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Model Boiler Cost Analysis for Controlling Particulate Matter (PM) Emissions from Small Steam Generating Units

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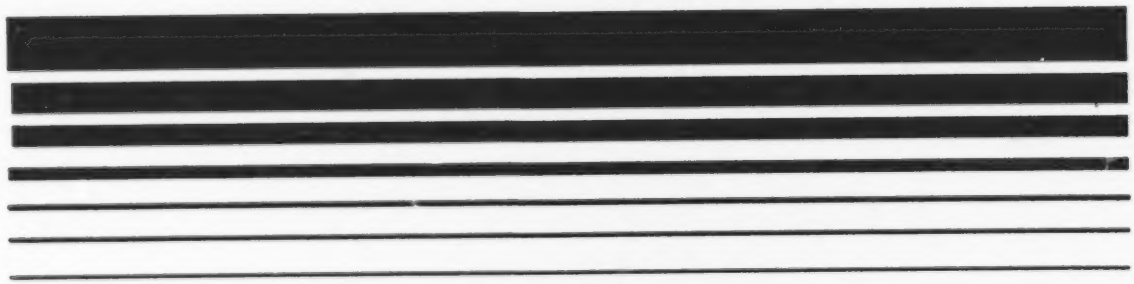

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This report presents estimates of the cost and cost effectiveness associated with controlling particulate matter emissions from small coal-, oil-, and wood-fired industrial-commercial-institutional steam generating units (small boilers). The report was prepared during development of proposed new source performance standards (NSPS) for small boilers (boilers with heat input capacities of 100 million Btu/hour or less).

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MODEL BOILER COST ANALYSIS FOR CONTROLLING PARTICULATE MATTER (PM) EMISSIONS FROM SMALL STEAM GENERATING UNITS

Emission Standards Division

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, N.C. 27711

May 1989

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1.0 INTRODUCTION

This report presents estimates of the costs and cost effectiveness associated with controlling particulate matter (PM) emissions from small coal-, oil-, and wood-fired steam generating units (i.e., boilers). The report was prepared as part of the project to develop new source performance standards (NSPS) for small boilers under Section 111 of the Clean Air Act. Small boilers are defined as industrial-commercial-institutional boilers having heat input capacities of 29 MW (100 million Btu/hour) or less. The regulatory baseline emission levels and alternative control levels used in this cost analysis are discussed in the reports entitled, "Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Sulfur Dioxide (SO_2) Emission Standards for Small Steam Generating Units" and "Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Particulate Matter (PM) Emission Standards for Small Steam Generating Units".[1,2]

2.0 SUMMARY

Capital, operating and maintenance (O&M), and annualized costs were estimated for model oil-, wood-, and coal-fired boilers and SO_2 and PM emissions control systems in EPA Region V. The PM emissions control techniques examined for oil-fired boilers were the use of medium sulfur oil, very low sulfur oil, wet flue gas desulfurization (FGD) systems or wet scrubbers, and electrostatic precipitators (ESPs). For coal-fired boilers, double mechanical collectors, sidestream separators, wet FGD systems or wet scrubbers, ESPs and fabric filters were examined. For wood-fired boilers, double mechanical collectors, wet scrubbers, and ESPs were examined.

Alternative control levels for standards limiting SO_2 emissions from oil and coal combustion can result in reduced PM emissions. In focusing on alternative control levels for standards limiting PM emissions from oil and coal combustion, therefore, any reduction in PM emissions associated with alternative control levels for standards limiting SO_2 emissions should be taken into account. Thus, alternative control levels for standards limiting PM emissions from oil and coal combustion were considered in relation to alternative control levels for standards limiting SO_2 emissions. The alternative control levels considered for standards limiting SO_2 and PM emissions are summarized in Tables 1 and 2, respectively. Because wood contains little or no sulfur, alternative control levels for standards limiting SO_2 emissions from wood combustion were not developed. Therefore, alternative control levels for standards limiting PM emissions from wood combustion are considered separately, with no relation to standards limiting SO_2 emissions.

SO_2 Alternative Control Level 1 for Oil-Fired Boilers

Alternative Control Level 1 for SO_2 emissions from small oil-fired boilers is 690 ng/J (1.60 lb/million Btu). This SO_2 emissions level is achieved by firing medium sulfur oil, which generates PM emissions of 73 ng/J (0.17 lb/million Btu) or less (PM Alternative Control Level A). The

annualized cost of firing medium sulfur oil ranges from $336,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,722,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Firing very low sulfur oil under PM Alternative Control Level B [43 ng/J (0.10 lb/million Btu)] increases the annualized costs by about 7 percent over PM Alternative Control Level A for all boiler sizes. Alternative Control Level C [22 ng/J (0.05 lb/million Btu)], based on the use of an ESP, increases annualized costs by 12 to 31 percent over Alternative Control Level A.

The incr mental cost effectiveness of emission control associated with PM Alternative Control Level B over PM Alternative Control Level A ranges from $14,000/Mg ($12,700/ton) at the 15 MW (50 million Btu/hour) boiler size and 0.55 capacity factor to $34,100/Mg ($30,900/ton) at the 22 MW (75 million Btu/hour) boiler size and 0.55 capacity factor.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from $13,500/Mg ($12,300/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.26 capacity factor to $1,930,000/Mg ($1,750,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

SO_2 Alternative Control Level 2 for Oil-Fired Boilers

Alternative Control Level 2 for SO_2 emissions from small oil-fired boilers is achieved by firing very low sulfur oil. The PM emission level that is achieved by firing very low sulfur oil is 43 ng/J (0.10 lb/million Btu) or less, which corresponds to PM Alternative Control Level B. The annualized cost of firing very low sulfur oil (PM Alternative Control Level B) ranges from $345,000/yr at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,916,000/yr at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Applying an ESP under PM Alternative Control Level C increases annualized costs by 12 to 30 percent. The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from

annualized cost of firing medium sulfur oil ranges from $336,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,722,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Firing very low sulfur oil under PM Alternative Control Level B [43 ng/J (0.10 lb/million Btu)] increases the annualized costs by about 7 percent over PM Alternative Control Level A for all boiler sizes. Alternative Control Level C [22 ng/J (0.05 lb/million Btu)], based on the use of an ESP, increases annualized costs by 12 to 31 percent over Alternative Control Level A.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level B over PM Alternative Control Level A ranges from $14,000/Mg ($12,700/ton) at the 15 MW (50 million Btu/hour) boiler size and 0.55 capacity factor to $34,100/Mg ($30,900/ton) at the 22 MW (75 million Btu/hour) boiler size and 0.55 capacity factor.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from $13,500/Mg ($12,300/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.26 capacity factor to $1,930,000/Mg ($1,750,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

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Alternative Control Level 2 for SO_2 emissions from small oil-fired boilers is achieved by firing very low sulfur oil. The PM emission level that is achieved by firing very low sulfur oil is 43 ng/J (0.10 lb/million Btu) or less, which corresponds to PM Alternative Control Level B. The annualized cost of firing very low sulfur oil (PM Alternative Control Level B) ranges from $345,000/yr at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,916,000/yr at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Applying an ESP under PM Alternative Control Level C increases annualized costs by 12 to 30 percent. The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from

$349,000/Mg ($317,000/ton) at the 29 MW (100 Million Btu/hour) boiler size and 0.55 capacity factor to $2,530,000/Mg ($2,290,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

SO_2 Alternative Control Level 3 for Oil-Fired Boilers

Alternative Control Level 3 for SO_2 emissions from small oil-fired boilers requires 90 percent SO_2 reduction. This alternative can be met by using an FGD system. Use of an FGD system achieves a PM emission level of 43 ng/J (0.10 lb/million Btu) which corresponds to PM Alternative Control Level B. The annualized costs for model oil-fired boilers and FGD systems (PM Alternative Control Level B) range from $648,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $3,375,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Adding an ESP to achieve PM Alternative Control Level C increases the annualized cost by 6 to 11 percent over PM Alternative Control Level B.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from $18,300/Mg ($16,600/ton) at the 29 MW (100 million Btu/hr) boiler size and 0.55 capacity factor to $93,900/Mg ($85,200/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

SO_2 Alternative Control Level 1 for Coal-Fired Boilers

Alternative Control Level 1 for SO_2 emissions from small coal-fired boilers is 520 ng/J (1.2 lb/million Btu) based on the use of low sulfur coal. The regulatory baseline for PM emissions is based on the use of single mechanical collectors. The annualized costs for model low sulfur coal-fired boilers at the PM regulatory baseline range from $638,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,955,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Dual mechanical collectors are the lowest cost option for meeting PM Alternative Control Level A for all model boilers examined.

Under PM Alternative Control Level B, sidestream separators are the lowest cost option for boiler sizes above 2.9 MW (10 million Btu/hour) heat input, while fabric filters are the lowest cost option for boiler sizes of 2.9 MW (10 million Btu/hour) and below.

Fabric filters are the lowest cost option for achieving PM Alternative Control Levels C and D for all model boilers examined. The alternative PM control levels increase annualized costs over the regulatory baseline PM emission level by the following amounts:

- Alternative Control Level A - 2 to 6 percent
- Alternative Control Level B - 3 to 9 percent
- Alternative Control Level C - 5 to 9 percent
- Alternative Control Level D - 5 to 9 percent

Fabric filters are generally designed and operated to achieve an emission level of 22 ng/J (0.05 lb/million Btu) or less (corresponding to PM Alternative Control Level D). However, because of their relatively low cost, fabric filters have been included for analysis at PM Alternative Control Levels B and C as well. Although PM Alternative Control Levels B and C limit PM emissions to 86 and 43 ng/J (0.20 and 0.10 lb/million Btu), respectively, the costs and incremental cost effectiveness for all fabric filters were calculated based on achieving an emission rate of 22 ng/J (0.05 lb/million Btu). Thus, there is no additional cost or cost effectiveness impact associated with increasing the stringency of alternative control levels when fabric filters are the lowest cost option for the two levels being compared.

The incremental cost effectiveness of PM emission control associated with PM Alternative Control Level A over the PM regulatory baseline ranges from $890/Mg ($810/ton) at the 29 MW (100 million Btu/hour) boiler size and

0.55 capacity factor to $22,600/Mg ($20,500/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness of emission control associated with PM Alternative Control Level B over PM Alternative Control Level A ranges from $3,270/Mg ($2,970/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $16,330/Mg ($14,820/ton) at the 7.3 MW (25 million Btu/hour) boiler size and 0.26 capacity factor. At the 2.9 MW (10 million Btu/hour) boiler size, the incremental cost effectiveness is $8,640/Mg ($7,850/ton).

The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B at the 2.9 MW (10 million Btu/hour) boiler size is $0/Mg ($0/ton) for both capacity factors. At the 7.3 MW (25 million Btu/hour) boiler size, the incremental cost effectiveness ranges from $610/Mg ($555/ton) to $1,550/Mg ($1,400/ton) for the two capacity factors examined. For boilers 15 MW (50 million Btu/hour) and larger, the incremental cost effectiveness remains nearly constant at approximately $5,130/Mg ($4,660/ton) and $2,450/Mg ($2,230/ton) when boilers are operating at capacity factors of 0.26 and 0.55, respectively.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level D over PM Alternative Control Level C is $0/Mg ($0/ton) for all boiler sizes and capacity factors.

SO_2 Alternative Control Level 2 for Coal-fired Boilers

Alternative Control Level 2 for SO_2 emissions from small coal-fired boilers requires 90 percent SO_2 reduction. This control level can be achieved by using either an FGD system or a fluidized bed combustion (FBC) unit. This level of SO_2 control corresponds to a level of a 43 ng/J (0.10 lb/million Btu) or less (PM Alternative Control Level C) for coal-fired boilers.

Annualized costs for systems achieving 90 percent SO_2 control (equivalent to PM Alternative Control Level C) range from $2,935,000/year at the 29 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to

$4,465,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. The increase in annualized cost associated with applying a fabric filter (PM Alternative Control Level D) over PM Alternative Control Level C for these boilers ranges from 2 to 7 percent. The incremental cost effectiveness of emission control associated with PM Alternative Control Level D over PM Alternative Control Level C averages about $42,000/Mg ($38,000/ton) at a capacity factor of 0.26 and near $14,000/Mg ($13,000/ton) at a capacity factor of 0.55.

Wood-Fired Boilers

The regulatory baseline for small wood-fired boilers is based on the use of single mechanical collectors. The annualized costs for systems at the regulatory baseline range from $511,000/yr at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $3,353,000/yr at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Alternative Control Level A increases the annualized costs by 2 to 7 percent over the regulatory baseline. Alternative Control Levels B and C increase the annualized costs over the regulatory baseline by 9 to 16 percent and 10 to 19 percent, respectively.

The incremental cost effectiveness of emission control associated with Alternative Control Level A over the regulatory baseline ranges from $900/Mg ($820/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $21,900/Mg ($19,900/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness of Alternative Control Level B over Alternative Control Level A ranges from $9,580/Mg ($8,690/ton) at the 22 MW (75 million Btu/hour) boiler size and 0.55 capacity factor to $39,700/Mg ($36,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness of Alternative Control Level C over Alternative Control Level B ranges from $1,330/Mg ($1,200/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $15,500/Mg ($14,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

3.0 MODEL BOILER COSTING METHODOLOGY

This model boiler cost analysis estimates capital, O&M, and annualized costs using methodologies discussed in References 3 through 7. The selection of model boiler types and sizes used in the analysis is covered in Reference 8. All costs are presented in June 1985 dollars. Capital and O&M costs were updated from other time bases using the Chemical Engineering plant cost and Bureau of Labor Statistics producer price indices, respectively. The total cost for each model system includes the costs of the boiler, fuel, and add-on PM and SO_2 control equipment, where applicable. The PM and SO_2 regulatory baseline emission levels and alternative control levels used in this analysis are presented in Tables 1 and 2.

Particulate matter emissions from oil combustion can be correlated with oil sulfur content.[9] Such correlations indicate that reductions in PM emissions are a secondary benefit associated with reducing SO_2 emissions through the combustion of low sulfur oils. Particulate matter emissions are also reduced if FGD systems are used to reduce SO_2 emissions from oil combustion.[10] As a result, standards limiting SO_2 emissions from oil combustion, either through combustion of medium or very low sulfur oils or the use of FGD systems, result in reductions in PM emissions.

In considering alternative control levels for standards to limit PM emissions from oil combustion, the reductions in PM emissions associated with alternative control levels for standards limiting SO_2 emissions from oil combustion should be taken into account. In focusing on alternative control levels for PM standards, therefore, this report considers these alternatives in relation to alternative control levels selected for SO_2 standards.[11]

Since PM emissions from coal, unlike oil, cannot be correlated to fuel sulfur content, limiting SO_2 emission from coal combustion through the use of low sulfur coal has no effect on PM emissions.[12] The use of FGD systems to limit SO_2 emissions from coal combustion, however, does result in reduced PM emissions.[13]

Consequently, alternative control levels for standards limiting SO_2 emissions from coal combustion can also result in reductions in PM emissions. In focusing on alternative control levels for standards limiting PM emissions from coal combustion, therefore, any reduction in PM emissions associated with alternative control levels for standards limiting SO_2 emissions should be taken into account. Thus, as with oil, alternative control levels for standards limiting PM emissions from coal combustion are considered in relation to alternative control levels for standards limiting SO_2 emissions.

Because wood contains little or no sulfur, alternative control levels for standards limiting SO_2 emissions from wood combustion were not developed. Therefore, alternative control levels for standards limiting PM emissions from wood combustion are considered separately, with no relation to standards limiting SO_2 emissions.

The fuel prices used in the analysis are presented in Table 3. These are projected prices for fuel delivered in EPA Region V, levelized over the period from 1992 to 2007.[14] Although Region V prices were used for illustrative purposes, fuel prices from other EPA Regions would be expected to produce similar cost results.

Costs for SO_2 compliance requirements are included for each model coal- and oil-fired system. These costs are discussed in Reference 15. It should be noted that the incremental cost effectiveness associated with PM emission control is not affected by the SO_2 compliance requirement specified because SO_2 compliance costs are equal between the PM alternative control levels compared. Cost differences among SO_2 compliance options are accounted for in the incremental cost effectiveness associated with SO_2 emission control.[15]

Costs for opacity monitors are included for the alternative PM control level cases to ensure PM emission compliance. Opacity monitors are not included for the PM regulatory baseline cases. Although opacity monitors would not actually be used when FGD systems are used for SO_2 control, opacity monitor costs are included as surrogate costs for other possible PM compliance options, such as monitoring of venturi scrubber pressure drop or liquid-to-gas ratio.[16]

4.0 MODEL BOILER COST ANALYSIS RESULTS

4.1 OIL

As discussed above, reductions in PM emissions associated with alternative control levels for standards limiting SO_2 emissions from oil combustion should be taken into account when considering alternative control levels for standards limiting PM emissions. Thus, costs and cost effectiveness are estimated for additional PM emission control on boilers achieving specified SO_2 emission standards.

4.1.1 SO_2 Alternative Control Level 1

Alternative Control Level 1 for SO_2 emissions from oil-fired boilers is 690 ng/J (1.60 lb/million Btu). This SO_2 emission level is achieved by firing medium sulfur oil, which generates PM emissions of 73 ng/J (0.17 lb/million Btu) or less. This PM emission rate is defined as PM Alternative Control Level A. Alternative Control Level B for PM emissions is 43 ng/J (0.10 lb/million Btu) based on the use of either very low sulfur oil or a wet scrubber. Alternative Control Level C for PM emissions is 22 ng/J (0.05 lb/million Btu) based on the use of an ESP. Tables 4 and 5 present the costs of these alternative PM control levels under SO_2 Alternative Control Level 1. The annualized cost of firing medium sulfur oil (PM Alternative Control Level A) ranges from $336,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,722,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Alternative Control Level B for PM emissions increases the annualized costs about 7 percent over PM Alternative Control Level A for all boiler sizes. Alternative Control Level C for PM emissions increases annualized costs by 12 to 31 percent over PM Alternative Control Level A.

Tables 6 and 7 present the results of the analysis for model boilers under SO_2 Alternative Control Level 1 operating at capacity factors of 0.26 and 0.55, respectively. The incremental cost effectiveness of emission control associated with PM Alternative Control Level B over PM Alternative Control Level A ranges from $14,000/Mg ($12,700/ton) at the 15 MW

(50 million Btu/hour) boiler size and 0.55 capacity factor to $34,100/Mg ($30,900/ton) at the 22 MW (75 million Btu/hour) boiler size and 0.55 capacity factor. The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from $13,500/Mg ($12,300/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $1,930,000/Mg ($1,750,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

The firing of very low sulfur oil is the lowest cost option to meet PM Alternative Control Level B for all boilers operating at a 0.26 capacity factor and for boilers with 15 MW (50 million Btu/hour) heat input or less operating at a 0.55 capacity factor. Application of a wet scrubber results in the lowest costs for the 22 and 29 MW (75 and 100 million Btu/hour) boilers operating at a 0.55 capacity factor.

When very low sulfur oil is fired to meet PM Alternative Control Level B, the incremental cost effectiveness decreases with increasing boiler size and capacity factor. This result is due to the addition of an opacity monitor to ensure PM emission compliance under PM Alternative Control Level B but not under PM Alternative Control Level A. Although the annualized cost for an opacity monitor remains constant for all boiler sizes and capacity factors, the annual PM emission reductions achieved increase with increasing boiler size and capacity factor. Thus, incremental cost effectiveness decreases. The incremental cost effectiveness increases at the 22 MW (75 million Btu/hour) boiler size and 0.55 capacity factor because application of a wet scrubber becomes the lowest cost option. The incremental cost effectiveness associated with PM Alternative Control Level C decreases with increasing boiler size and capacity factor due to the economies of scale associated with ESP applications.

4.1.2 SO_2 Alternative Control Level 2

Alternative Control Level 2 for SO_2 emissions is achieved by firing very low sulfur oil. The PM emission level that is achieved by firing very low sulfur oil is 43 ng/J (0.10 lb/million Btu) or less which corresponds to

PM Alternative Control Level B. Alternative Control Level C for PM emissions can be achieved by applying an ESP. Tables 8 and 9 present the costs of these alternative PM control levels under SO_2 Alternative Control Level 2. The annualized cost of firing very low sulfur oil (PM Alternative Control Level B) ranges from $345,000/yr at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,916,000/yr at the 29 MW (100 million Btu/hour) and 0.55 capacity factor. Applying an ESP under PM Alternative Control Level C increases annualized costs by 12 to 30 percent.

Tables 10 and 11 present the results of the analysis for model boilers under SO_2 Alternative Control Level 2. The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B ranges from $349,000/Mg ($317,000/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $2,530,000/Mg ($2,290,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness increases with decreasing boiler size and capacity factor due to the economies of scale associated with ESP applications.

4.1.3 SO_2 Alternative Control Level 3

Alternative Control Level 3 for SO_2 emissions from oil-fired boilers requires 90 percent SO_2 reduction. This level can be achieved by using an FGD system. As discussed in Reference 2, an FGD system can reduce PM emissions from oil-fired boilers to 43 ng/J (0.10 lb/million Btu). This reduction corresponds to PM Alternative Control Level B. Alternative Control Level C for PM emissions can be achieved by applying an ESP upstream of the FGD system.

Tables 12 and 13 present the costs associated with model oil-fired boilers and FGD systems (PM Alternative Control Level B) operating at capacity factors of 0.26 and 0.55, respectively. The annualized costs for these systems range from $648,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $3,375,000/year at the 29 MW

(100 million Btu/hour) boiler size and 0.55 capacity factor. Adding an ESP to achieve PM Alternative Control Level C increases the annualized cost by 6 to 11 percent over PM Alternative Control Level B.

Tables 14 and 15 present the results of the analysis for the model oil-fired boilers under SO_2 Alternative Control Level 3. The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over Alternative Control Level B ranges from $18,300/Mg ($16,600/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $93,900/Mg ($85,200/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

The incremental cost effectiveness decreases with increasing boiler size and capacity factor. This result is primarily due to the economies of scale associated with ESP applications and the inclusion of an opacity monitor under PM Alternative Control Level C but not under PM Alternative Control Level B.

4.2 COAL

As discussed above, reductions in PM emissions associated with alternative control levels for standards limiting SO_2 emissions from coal combustion should be taken into account when considering alternative control levels for standards limiting PM emissions. Thus, costs and cost effectiveness are estimated for additional PM emission control on boilers achieving SO_2 emissions standards.

4.2.1 SO_2 Alternative Control Level 1

Alternative Control Level 1 for SO_2 emissions from coal-fired boilers is 520 ng/J (1.2 lb/million Btu) based on the use of low sulfur coal. The regulatory baseline for PM emissions is based on the use of single mechanical collectors. As discussed in Reference 2, this level is 190 ng/J (0.45 lb/million Btu) for boilers smaller than 8.7 MW (30 million Btu/hour) heat input and 260 ng/J (0.60 lb/million Btu) for boilers of 8.7 MW (30 million Btu/hour) and larger. Alternative Control Levels A, B, C, and D

for PM emissions are 130, 86, 43, and 22 ng/J (0.30, 0.20, 0.10, and 0.05 lb/million Btu), respectively. Tables 16 and 17 present the costs of these PM control levels under SO_2 Alternative Control Level 1.

The annualized costs for model boilers at the PM regulatory baseline range from $638,000/year at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $2,955,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Dual mechanical collectors are the lowest cost option for meeting PM Alternative Control Level A for all model boilers examined. Under PM Alternative Control Level B, sidestream separators are the lowest cost option for boilers above 2.9 MW (10 million Btu/hour) heat input, while fabric filters are the lowest cost option for boilers 2.9 MW (10 million Btu/hour) and below. Fabric filters are the lowest cost option for achieving both PM Alternative Control Levels C and D for all model boilers examined. The alternative PM control levels increase annualized costs over the PM regulatory baseline by the following amounts:

- Alternative Control Level A - 2 to 6 percent
- Alternative Control Level B - 3 to 9 percent
- Alternative Control Level C - 5 to 9 percent
- Alternative Control Level D - 5 to 9 percent

Tables 18 and 19 present the results of the analysis for model boilers under SO_2 Alternative Control Level 1 operating at capacity factors of 0.26 and 0.55, respectively. The incremental cost effectiveness of emission control associated with PM Alternative Control Level A over the PM regulatory baseline ranges from $890/Mg ($810/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $22,600/Mg ($22,500/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness of emission control associated with PM Alternative Control Level B over PM Alternative Control Level A ranges from $3,270/Mg ($2,970/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $16,330/Mg ($14,820/ton) at the 7.3 MW (25 million Btu/hour) boiler size and 0.26 capacity factor.

The incremental cost effectiveness of PM Alternative Control Level B over PM Alternative Control Level A and PM Alternative Control Level A over the PM regulatory baseline generally increases with decreasing boiler size and capacity factor. This result is due to the economies of scale associated with the PM control technologies applied. The only case which deviates from this trend is at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor, where fabric filters are the lowest cost option to meet PM Alternative Control Level B. For all other cases, sidestream separators are the lowest cost option to meet this regulatory alternative. Thus, two different technologies and actual emission rates are being compared.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level C over PM Alternative Control Level B at the 2.9 MW (10 million Btu/hour) boiler size is $0/Mg ($0/ton) for both capacity factors. At the 7.3 MW (25 million Btu/hour) boiler size, the incremental cost effectiveness ranges from $610/Mg ($550/ton) to $1,550/Mg ($1,400/ton) for the two capacity factors examined. For boilers 15 MW (50 million Btu/hour) and larger, the incremental cost effectiveness remains nearly constant at approximately $5,130/Mg ($4,660/ton) and $2,450/Mg ($2,230/ton) when operating at capacity factors of 0.26 and 0.55, respectively.

At the 2.9 MW (10 million Btu/hour) boiler size, fabric filters are the lowest cost option to meet PM Alternative Control Levels B and C. Fabric filters are generally designed and operated to achieve an emission level of 22 ng/J (0.05 lb/million Btu) or less (PM Alternative Control Level D). However, because of their relatively low cost, fabric filters have been included for analysis at PM Alternative Control Levels B and C as well. Although Alternative Control Levels B and C limit PM emissions to 86 and 43 ng/J (0.20 and 0.10 lb/million Btu), respectively, the costs and incremental cost effectiveness for all fabric filters were calculated based on achieving an emission rate of 22 ng/J (0.05 lb/million Btu). Thus, there is no additional cost or cost effectiveness impact associated with increasing the stringency of alternative control levels when fabric filters are the lowest cost option for the two levels being compared. As a result, the incremental cost effectiveness is $0/Mg ($0/ton).

At the other boiler sizes, sidestream separators and fabric filters are the lowest cost options to meet PM Alternative Control Levels B and C, respectively. Fabric filter costs increase more rapidly with size than sidestream separator costs for boilers up to 8.7 MW (30 million Btu/hour) heat input. However, for boiler sizes above 8.7 MW (30 million Btu/hour), costs for fabric filters and sidestream separators increase with boiler size at nearly equal rates. Thus, the incremental cost effectiveness increases with boiler size up to 8.7 MW (30 million Btu/hour) and then becomes nearly constant as size increases.

The incremental cost effectiveness of emission control associated with PM Alternative Control Level D over PM Alternative Control Level C is $0/Mg ($0/ton) for all boiler sizes and capacity factors. This result is due to fabric filters being the lowest cost option at both alternative control levels. That is, as discussed above, fabric filter control performance and costs do not change between alternative control levels.

4.2.2 SO_2 Alternative Control Level 2

Alternative Control Level 2 for SO_2 emissions from coal-fired boilers requires 90 percent SO_2 reduction. This control level can be achieved by using either an FGD system or an FBC unit. As discussed in Reference 17, the costs for achieving 90 percent SO_2 reduction under SO_2 Alternative Control Level 2 are based on costs for FGD. When an FGD system is used to meet SO_2 Alternative Control Level 2, PM emissions will be reduced to 43 ng/J (0.10 lb/million Btu) or less. This PM emission level corresponds to PM Alternative Control Level C for coal-fired boilers. Alternative Control Level D for PM emissions is 22 ng/J (0.05 lb/million Btu) based on the use of a fabric filter.

Tables 20 and 21 present the costs of the alternative PM control levels for coal-fired boilers under SO_2 Alternative Control Level 2. Annualized costs for the boilers with FGD systems (PM Alternative Control Level C) range from $2,935,000/year at the 29 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $4,465,000/year at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. The increase in annualized cost associated with PM Alternative Control Level D over PM Alternative Control Level C ranges from 2 to 7 percent.

Tables 22 and 23 present the results of the analysis for coal-fired boilers operating at capacity factors of 0.26 and 0.55, respectively. The incremental cost effectiveness of emission control associated with PM Alternative Control Level D over PM Alternative Control Level C averages approximately $42,000/Mg ($38,000/ton) at a capacity factor of 0.26 and near $14,000/Mg ($13,000/ton) at a capacity factor of 0.55.

Fabric filter costs increase more rapidly with size for boilers smaller than 8.7 MW (30 million Btu/hour) than for those above this size. Therefore, the incremental cost effectiveness increases as boiler sizes approach the 8.7 to 15 MW (30 to 50 million Btu/hour) size range, but then begins to decrease for the larger systems. However, as the capacity factor increases, the emissions reductions associated with these costs also increase. Thus, the incremental cost effectiveness decreases with increasing capacity factors.

4.3 WOOD

As discussed above, since wood contains little or no sulfur, alternative control levels for standards limiting SO_2 emissions from wood combustion were not developed. Therefore, alternative control levels for standards limiting PM emissions from wood combustion are considered separately, with no relation to standards limiting SO_2 emissions.

The regulatory baseline for PM emissions is 190 ng/J (0.45 lb/million Btu) for boilers smaller than 8.7 MW (30 million Btu/hour) heat input and 260 ng/J (0.60 lb/million Btu) for boilers larger than or equal to this size; these levels are based on the use of a single mechanical collector. Alternative Control Level A is 130 ng/J (0.30 lb/million Btu) based on the use of a double mechanical collector. Alternative Control Level B is 86 ng/J (0.20 lb/million Btu) based on the use of either an ESP or a wet scrubber operated at a low pressure drop. The lowest cost option to meet Alternative Control Level B for all boilers except the largest [29 MW (100 million Btu/hour)] boilers at both capacity factors is the use of an ESP. Alternative Control Level C is 43 ng/J (0.10 lb/million Btu) based on the use of either an ESP or a wet scrubber operating at a medium pressure drop. Use of an ESP is again the lowest cost option to meet Alternative Control

Level C for all boilers except the largest [29 MW (100 million Btu/hour)] boilers at both capacity factors.

Tables 24 and 25 present the costs of the Alternative Control Levels for wood-fired boilers. The annualized costs for a wood-fired boilers with a single mechanical collectors (regulatory baseline) range from $511,000/yr at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor to $3,353,000/yr at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor. Alternative Control Level A increases the annualized costs by 2 to 7 percent over the regulatory baseline. Alternative Control Levels B and C increase the annualized costs over the regulatory baseline by 9 to 16 percent and 10 to 19 percent, respectively.

Tables 26 and 27 present the results of the analysis for wood-fired boilers at capacity factors of 0.26 and 0.55, respectively. The incremental cost effectiveness of emission control associated with Alternative Control Level A over the regulatory baseline ranges from $900/Mg ($820/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $21,900/Mg ($19,900/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness of Alternative Control Level B over Alternative Control Level A ranges from $9,580/Mg ($8,690/ton) at the 22 MW (75 million Btu/hour) boiler size and 0.55 capacity factor to $39,700/Mg ($36,100/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor. The incremental cost effectiveness of Alternative Control Level C over Alternative Control Level B ranges from $1,330/Mg ($1,200/ton) at the 29 MW (100 million Btu/hour) boiler size and 0.55 capacity factor to $15,500/Mg ($14,000/ton) at the 2.9 MW (10 million Btu/hour) boiler size and 0.26 capacity factor.

The incremental cost effectiveness associated with each alternative control level generally decreases with increasing boiler sizes and capacity factors. This result is due to the economies of scale associated with the PM control devices applied. The only cases that deviate from this trend are under Alternative Control Level B at the 29 MW (100 million Btu/hour) boiler size for both capacity factors. For these systems, the incremental cost effectiveness increases because a different PM control device is chosen to meet the Alternative Control Level.

5.0 REFERENCES

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TABLE 1. SO_2 ALTERNATIVE CONTROL LEVELS FOR SMALL BOILERS

	SO_2 Emission Standard	Basis
Coal-Fired Boilers		
Regulatory baseline	1,550 ng/J (3.6 lb/million Btu)	Medium sulfur coal[a]
Alternative Control Level 1	520 ng/J (1.2 lb/million Btu)	Low sulfur coal[b]
Alternative Control Level 2	90% SO_2 reduction	FGD or FBC[c]
Oil-Fired Boilers		
Regulatory baseline	1,290 ng/J (3.0 lb/million Btu)	High sulfur oil
Alternative Control Level 1	690 ng/J (1.6 lb/million Btu)	Low sulfur oil
Alternative Control Level 2	210 ng/J (0.50 lb/million Btu)	Very low sulfur oil
Alternative Control Level 3	90% SO_2 reduction	FGD

[a]Type F - bituminous

[b]Type B - bituminous

[c]FGD = Flue Gas Desulfurization
FBC = Fluidized Bed Combustion

SOURCE: Reference 1.

TABLE 2. PM ALTERNATIVE CONTROL LEVELS FOR SMALL OIL-, COAL-, AND WOOD-FIRED BOILERS

	PM Emission Standard	Basis[a]
Oil-Fired Boilers		
Regulatory Baseline	95 ng/J (0.22 lb/million Btu)	HSO
Alternative Control Level A	73 ng/J (0.17 lb/million Btu)	MSO
Alternative Control Level B	43 ng/J (0.10 lb/million Btu)	WS or VLSO
Alternative Control Level C	22 ng/J (0.05 lb/million Btu)	ESP
Coal-Fired Boilers		
Regulatory Baseline		
<8.7 MW (30 million Btu/hour)	190 ng/J (0.45 lb/million Btu)	SMC
≥8.7 MW (30 million Btu/hour)	260 ng/J (0.60 lb/million Btu)	SMC
Alternative Control Level A	130 ng/J (0.30 lb/million Btu)	DMC
Alternative Control Level B	86 ng/J (0.20 lb/million Btu)	SSS
Alternative Control Level C	43 ng/J (0.10 lb/million Btu)	SMC+WS
Alternative Control Level D	22 ng/J (0.05 lb/million Btu)	FF or SMC+ ESP

TABLE 2. PM ALTERNATIVE CONTROL LEVELS FOR SMALL OIL-, COAL-, AND WOOD FIRED BOILERS (continued)

	PM Emission Standard	Basis[a]
Wood-Fired Boilers		
Regulatory Baseline		
<8.7 MW (30 million Btu/hour)	190 ng/J (0.45 lb/million Btu)	SMC
≥8.7 MW (30 million Btu/hour)	260 ng/J (0.60 lb/million Btu)	SMC
Alternative Control Level A	130 ng/J (0.30 lb/million Btu)	DMC
Alternative Control Level B	86 ng/J (0.20 lb/million Btu)	SMC+ESP or SMC+WS (low pressure drop)
Alternative Control Level C	43 ng/J (0.10 lb/million Btu)	SMC+ESP or SMC+WS (medium pressure drop)

[a]SMC = Single Mechanical Collector
DMC = Double Mechanical Collector
SSS = Sidestream Separator
FF = Fabric Filter
ESP = Electrostatic Precipitator
WS = Wet Flue Gas Desulfurization System (or Wet Scrubber)
HSO = High Sulfur Oil
MSO = Medium Sulfur Oil
VLSO = Very Low Sulfur Oil

TABLE 3. PROJECTED FUEL PRICES FOR EPA REGION V

	$/GJ ($/million Btu)[a]
Coal:	
Low sulfur bituminous	2.73 (2.88)
Medium sulfur bituminous	2.38 (2.51)
Oil:	
Medium sulfur	5.18 (5.46)
Very low sulfur	4.07 (4.30)
Natural Gas:[b]	4.49 (4.73)

[a]Levelized prices in June 1985 dollars.

[b]Industrial noncarriage market price. Used during FGD malfunction.

SOURCE: Reference 14.

Table 4. Model Boiler Cost Analysis for Particulate Matter Control Alternatives on Medium Sulfur Oil-fired Boilers in Region V at 0.26 Capacity Factor (a,b)

Boiler Size PM Control Technique - Alternative Control Level (c,d)	PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	1.32 (1.45)	445	89	175	264	336
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	1.03 (1.13)	648	89	209	298	403
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	0.55 (0.61)	505	98	183	281	361
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	0.51 (0.57)	849	89	213	302	441
7.3 MW (25 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	3.29 (3.63)	734	222	232	454	573
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	2.57 (2.83)	991	222	274	496	656
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.39 (1.53)	794	245	239	484	612
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.28 (1.41)	1,410	222	275	497	729
15 MW (50 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	6.58 (7.25)	1,483	444	275	719	963
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	5.13 (5.65)	1,830	444	329	773	1,074
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.77 (3.06)	1,546	490	282	772	1,025
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.57 (2.83)	2,550	444	325	769	1,192

(Continued)

Table 4. Model Boiler Cost Analysis for Particulate Matter Control Alternatives on Medium Sulfur Oil-fired Boilers in Region V at 0.26 Capacity Factor (a,b) (Continued)

Boiler Size PM Control Technique - Alternative Control Level (c,d)	PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
22 MW (75 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	9.87 (10.88)	1,903	666	319	985	1,299
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	7.70 (8.48)	2,341	666	385	1,051	1,437
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	4.16 (4.58)	1,968	735	326	1,061	1,384
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	3.85 (4.24)	3,279	666	375	1,041	1,587
29 MW (100 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	13.16 (14.51)	2,281	888	362	1,250	1,626
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	10.26 (11.31)	2,810	888	441	1,329	1,792
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.55 (6.11)	2,348	979	370	1,349	1,734
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.13 (5.65)	3,823	888	424	1,312	1,948

a All costs in June 1985 dollars.

b Compliance option costs at the PM baseline (i.e., MSO) include shipment fuel sampling/analysis. The PM control alternatives Level B and C (i.e., VS or VLSO and ESP, respectively) costs include shipment fuel sampling/anslysis and opacity monitors.

c MSO = Medium sulfur oil
VS = Venturi scrubber
VLSO = Very low sulfur oil
ESP = Electrostatic precipitator

d The VLSO option is based on very low sulfur residual oil rather than distillate oil which would have higher model costs.

Table 5. Model Boiler Cost Analysis for Particulate Matter Control Alternatives on Medium Sulfur Oil-fired Boilers in Region V at 0.55 Capacity Factor (a,b)

Boiler Size PM Control Technique - Alternative Control Level (c,d)	PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	2.78 (3.07)	462	188	220	408	482
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	2.17 (2.39)	666	188	260	448	554
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.17 (1.29)	523	207	228	435	518
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.09 (1.20)	867	188	266	454	595
7.3 MW (25 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	6.96 (7.67)	766	470	292	762	885
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	5.43 (5.98)	1,025	470	343	813	977
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.93 (3.23)	829	518	301	819	950
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.71 (2.99)	1,445	470	344	814	1,050
15 MW (50 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	13.92 (15.34)	1,539	940	346	1,286	1,537
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	10.85 (11.96)	1,889	940	414	1,354	1,661
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.87 (6.46)	1,606	1,036	355	1,391	1,650
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.43 (5.98)	2,608	940	407	1,347	1,776

(Continued)

Table 5. Model Boiler Cost Analysis for Particulate Matter Control Alternatives on Medium Sulfur Oil-fired Boilers in Region V at 0.55 Capacity Factor (a,b) (Continued)

Boiler Size PM Control Technique - Alternative Control Level (c,d)	PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
22 MW (75 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	20.89 (23.02)	1,982	1,409	402	1,811	2,133
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	16.28 (17.94)	2,424	1,409	487	1,896	2,290
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	8.80 (9.70)	2,053	1,554	410	1,964	2,295
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	8.14 (8.97)	3,361	1,409	471	1,880	2,434
29 MW (100 MMBtu/hr)							
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	27.85 (30.69)	2,382	1,879	456	2,335	2,722
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	21.71 (23.92)	2,916	1,879	559	2,438	2,911
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	11.73 (12.93)	2,458	2,072	464	2,536	2,932
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	10.85 (11.96)	3,927	1,879	533	2,412	3,058

a All costs in June 1985 dollars.

b Compliance option costs at the PM baseline (i.e., MSO) include shipment fuel sampling/analysis. The PM control alternatives Level B and C (i.e., VS or VLSO and ESP, respectively) costs include shipment fuel sampling/anslysis and opacity monitors.

c MSO = Medium sulfur oil
VS = Venturi scrubber
VLSO = Very low sulfur oil
ESP = Electrostatic precipitator

d The VLSO option is based on very low sulfur residual oil rather than distillate oil which would have higher model costs.

Table 6. Cost Effectiveness for Additional PM Control on Medium Sulfur Oil-fired Boilers at 0.26 Capacity Factor (a,b)

Boiler Size PM Control Technique - Alternative Control Level (c,d,e)	PM Emission Rate ng/(lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, ($1000/yr)	Average Cost Effectiveness, $/Mg ($/ton)	Incremental Cost Eeffectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	1.32 (1.45)	336	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	0.55 (0.61)	361	32,800 (29,800)	33,000 (30,000)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	0.51 (0.57)	441	131,000 (119,000)	1,930,000 (1,750,000)
7.3 MW (25 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	3.29 (3.63)	573	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.39 (1.53)	612	20,500 (18,600)	20,500 (18,600)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.28 (1.41)	729	77,700 (70,500)	1,130,000 (1,020,000)
15 MW (50 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	6.58 (7.25)	963	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.77 (3.06)	1,025	16,300 (14,800)	16,300 (14,800)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.57 (2.83)	1,192	57,000 (51,700)	804,000 (729,000)

(Continued)

Table 6. Cost Effectiveness for Additional PM Control on Medium Sulfur Oil-fired Boilers at 0.26 Capacity Factor (a,b) (Continued)

Boiler Size PM Control Technique - Alternative Control Level (c,d,e)	PM Emission Rate ng/(lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, ($1000/yr)	Average Cost Effectiveness, $/Mg ($/ton)	Incremental Cost Effectiveness, $/Mg ($/ton)
22 MW (75 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	9.87 (10.88)	1,299	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	4.16 (4.58)	1,384	14,900 (13,500)	14,900 (13,500)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	3.85 (4.24)	1,587	47,800 (43,400)	651,000 (591,000)
29 MW (100 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	13.16 (14.51)	1,626	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.55 (6.11)	1,734	14,200 (12,900)	14,200 (12,900)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.13 (5.65)	1,948	40,100 (36,400)	515,000 (467,000)

a All costs in June 1985 dollars.
b Compliance option costs at the PM baseline (i.e., MSO) include shipment fuel sampling/analysis. The PM control alternatives Level B and C (i.e., VS or VLSO and ESP, respectively) costs include shipment fuel sampling/anslysis and opacity monitors.
c MSO = Medium sulfur oil
VS = Venturi scrubber
VLSO = Very low sulfur oil
ESP = Electrostatic precipitator
d The VLSO option is based on very low sulfur residual oil rather than distillate oil which would have higher cost effectiveness values.
e The least cost option for Level B from the VS and VLSO control options.

Table 7. Cost Effectiveness for Additional PM Control on Medium Sulfur Oil-fired Boilers at 0.55 Capacity Factor (a,b)

Boiler Size PM Control Technique - Alternative Control Level (c,d,e)	PM Emission Rate ng/(lb/MMBtu)	Annual Emissions, Mg/yr(ton/yr)	Annualized Cost, ($1000/yr)	Average Cost Effectiveness, $/Mg ($/ton)	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	2.78 (3.07)	482	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.17 (1.29)	518	22,300 (20,300)	22,300 (20,300)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.09 (1.20)	595	66,500 (60,300)	876,000 (795,000)
7.3 MW (25 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	6.96 (7.67)	885	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.93 (3.23)	950	16,100 (14,600)	16,100 (14,600)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.71 (2.99)	1,050	38,800 (35,200)	455,000 (413,000)
15 MW (50 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	13.92 (15.34)	1,537	- -	- -
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.87 (6.46)	1,650	14,000 (12,700)	14,000 (12,700)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.43 (5.98)	1,776	28,100 (25,500)	287,000 (260,000)

(Continued)

Table 7. Cost Effectiveness for Additional PM Control on Medium Sulfur Oil-fired Boilers at 0.55 Capacity Factor (a,b) (Continued)

Boiler Size PM Control Technique - Alternative Control Level (c,d,e)	PM Emission Rate ng/(lb/MMBtu)	Annual Emissions, Mg/yr(ton/yr)	Annualized Cost, ($1000/yr)	Average Cost effectiveness, $/Mg ($/ton)	Incremental Cost Effectiveness, $/Mg ($/ton)
22 MW (75 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	20.89 (23.02)	2,133	- -	- -
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	16.28 (17.94)	2,290	34,100 (30,900)	34,100 (30,900)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	8.14 (8.97)	2,434	23,600 (21,400)	17,700 (16,100)
29 MW (100 MMBtu/hr)					
Level A/MSO - 0.17 LB PM/MMBtu	55 (0.128)	27.85 (30.69)	2,722	- -	- -
Level B/VS - 0.10 LB PM/MMBtu	43 (0.100)	21.71 (23.92)	2,911	30,800 (27,900)	30,800 (27,900)
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	10.85 (11.96)	3,058	19,800 (17,900)	13,500 (12,300)

a All costs in June 1985 dollars.
b Compliance option costs at the PM baseline (i.e., MSO) include shipment fuel sampling/analysis. The PM control alternatives Level B and C (i.e., VS or VLSO and ESP, respectively) costs include shipment fuel sampling/anslysis and opacity monitors.
c MSO = Medium sulfur oil
VS = Venturi scrubber
VLSO = Very low sulfur oil
ESP = Electrostatic precipitator
d The VLSO option is based on very low sulfur residual oil rather than distillate oil which would have higher cost effectiveness values.
e The least cost option for Level B from the VS and VLSO control options.

Table 8. Model Boiler Cost Analysis for Particulate Matter Control Alternatives on Very Low Sulfur Oil-fired Boilers in Region V at 0.26 Capacity Factor (a,b)

Boiler Size PM Control Technique - Nominal Emission Rate (c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	0.55 (0.61)	446	98	175	273	345
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	0.51 (0.57)	850	98	214	312	450
7.3 MW (25 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.39 (1.53)	735	245	231	476	596
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.28 (1.41)	1,412	245	274	519	752
15 MW (50 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.77 (3.06)	1,487	490	274	764	1,009
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.57 (2.83)	2,553	490	324	814	1,238
22 MW (75 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	4.16 (4.58)	1,909	735	318	1,053	1,368
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	3.85 (4.24)	3,285	735	374	1,109	1,655
29 MW (100 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.55 (6.11)	2,289	979	362	1,341	1,718
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.13 (5.65)	3,830	979	424	1,403	2,039

a All costs in June 1985 dollars.

b Compliance option costs at the PM baseline (i.e., VLSO) include shipment fuel sampling/analysis. The PM control alternative Level C (i.e., ESP) costs include shipment fuel sampling/anslysis and opacity monitors.

c VLSO = Very low sulfur oil
ESP = Electrostatic precipitator

Table 9. Model Boiler Cost Analysis for Particulate Matter Control Alternatives on Very Low Sulfur Oil-fired Boilers in Region V at 0.55 Capacity Factor (a,b)

Boiler Size/Control - Nominal Emission Rate	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.17 (1.29)	464	207	220	427	502
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.09 (1.20)	869	207	267	474	614
7.3 MW (25 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.93 (3.23)	770	518	293	811	934
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.71 (2.99)	1,449	518	344	862	1,098
15 MW (50 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.87 (6.46)	1,547	1,036	347	1,383	1,634
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.43 (5.98)	2,616	1,036	407	1,443	1,873
22 MW (75 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	8.80 (9.70)	1,994	1,554	402	1,956	2,279
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	8.14 (8.97)	3,372	1,554	471	2,025	2,579
29 MW (100 MMBtu/hr)							
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	11.73 (12.93)	2,399	2,072	456	2,528	2,916
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	10.85 (11.96)	3,943	2,072	533	2,605	3,252

a All costs in June 1985 dollars.

b Compliance option costs at the PM baseline (i.e., VLSO) include shipment fuel sampling/analysis. The PM control alternative Level C (i.e., ESP) costs include shipment fuel sampling/anslysis and opacity monitors.

c VLSO = Very low sulfur oil
ESP = Electrostatic precipitator

Table 10. Cost Effectiveness for Additional PM Control on Very Low Sulfur Oil-fired Boilers at 0.26 Capacity Factor (a,b)

Boiler Size PM Control Technique - Nominal Emission Rate (c,d)	Actual PM Emission Rate, ng/J (lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, ($1000/yr)	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	0.55 (0.61)	345	- -
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	0.51 (0.57)	450	2,530,000 (2,290,000)
7.3 MW (25 MMBtu/hr)				
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.39 (1.53)	596	- -
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.28 (1.41)	752	1,500,000 (1,360,000)
15 MW (50 MMBtu/hr)				
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.77 (3.06)	1,009	- -
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.57 (2.83)	1,238	1,100,000 (1,000,000)
22 MW (75 MMBtu/hr)				
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	4.16 (4.58)	1,368	- -
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	3.85 (4.24)	1,655	921,000 (836,000)
29 MW (100 MMBtu/hr)				
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.55 (6.11)	1,718	- -
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.13 (5.65)	2,039	772,000 (701,000)

a All costs in June 1985 dollars.

b Compliance option costs at the PM baseline (i.e., VLSO) include shipment fuel sampling/analysis. The PM control alternative Level C (i.e., ESP) costs include shipment fuel sampling/anslysis and opacity monitors.

c VLSO = Very low sulfur oil
ESP = Electrostatic precipitator

Table 11. Cost Effectiveness for Additional PM Control on Very Low Sulfur Oil-fired Boilers at 0.55 Capacity Factor (a,b)

Boiler Size PM Control Technique - Nominal Emission Rate (c,d)	Actual PM Emission Rate, ng/J (lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, ($1000/yr)	Incremental Cost Effectiveness, $/Mg	($/ton)
2.9 MW (10 MMBtu/hr)					
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	1.17 (1.29)	502	-	-
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	1.09 (1.20)	614	1,270,000	(1,160,000)
7.3 MW (25 MMBtu/hr)					
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	2.93 (3.23)	934	-	-
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	2.71 (2.99)	1,098	750,000	(680,000)
15 MW (50 MMBtu/hr)					
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	5.87 (6.46)	1,634	-	-
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	5.43 (5.98)	1,873	540,000	(490,000)
22 MW (75 MMBtu/hr)					
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	8.80 (9.70)	2,279	-	-
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	8.14 (8.97)	2,579	455,000	(413,000)
29 MW (100 MMBtu/hr)					
Level B/VLSO - 0.10 LB PM/MMBtu	23 (0.054)	11.73 (12.93)	2,916	-	-
Level C/ESP - 0.05 LB PM/MMBtu	21 (0.050)	10.85 (11.96)	3,252	382,000	(347,000)

a All costs in June 1985 dollars.

b Compliance option costs at the PM baseline (i.e., VLSO) include shipment fuel sampling/analysis. The PM control alternative Level C (i.e., ESP) costs include shipment fuel sampling/anslysis and opacity monitors.

c VLSO = Very low sulfur oil
ESP = Electrostatic precipitator

Table 12. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Oil-fired Boilers Subject to a Percent Reduction Requirement in Region V at 0.26 Capacity Factor (a)

Boiler Size PM Control Technique (b,c,d)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level B/PR	43 (0.10)	1.0 (1.1)	1,172	84	374	458	648
Level C/PR-ESP	22 (0.05)	0.5 (0.6)	1,373	84	389	473	696
7.3 MW (25 MMBtu/hr)							
Level B/PR	43 (0.10)	2.6 (2.8)	1,682	211	455	666	942
Level C/PR-ESP	22 (0.05)	1.3 (1.4)	2,130	211	470	681	1,032
14.6 MW (50 MMBtu/hr)							
Level B/PR	43 (0.10)	5.2 (5.7)	2,699	421	536	957	1,406
Level C/PR-ESP	22 (0.05)	2.6 (2.8)	3,489	421	549	970	1,553
22.0 MW (75 MMBtu/hr)							
Level B/PR	43 (0.10)	7.7 (8.5)	3,341	632	615	1,247	1,805
Level C/PR-ESP	22 (0.05)	3.9 (4.3)	4,387	632	627	1,259	1,994
29.3 MW (100 MMBtu/hr)							
Level B/PR	43 (0.10)	10 (11)	3,921	843	691	1,534	2,186
Level C/PR-ESP	22 (0.05)	5.2 (5.7)	5,074	843	700	1,543	2,395

a All costs are in June 1985 dollars.

b PR = 90% SO2 removal (based on flue gas desulfurization)
ESP = Electrostatic precipitator

c The compliance option costs at the Baseline (PR) are the costs associated with daily fuel sampling/analysis at the FGD inlet and continuous SO2 emission monitoring at the FGD outlet.

d The PM control alternative (PR-ESP) include inlet fuel sampling/analysis, an outlet SO2 CEM, and surrogate costs for control device performance monitoring (instead of opacity CEM).

Table 13. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Oil-fired Boilers Subject to a Percent Reduction Requirement in Region V at 0.55 Capacity Factor (a,b)

Boiler Size PM Control Technique (b,c,d)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
2.9 MW (10 MMBtu/hr)							
Level B/PR	43 (0.10)	2.2 (2.4)	1,194	178	452	630	824
Level C/PR-ESP	22 (0.05)	1.1 (1.2)	1,396	178	470	648	876
7.3 MW (25 MMBtu/hr)							
Level B/PR	43 (0.10)	5.5 (6.0)	1,723	446	565	1,011	1,295
Level C/PR-ESP	22 (0.05)	2.7 (3.0)	2,172	446	581	1,027	1,386
14.6 MW (50 MMBtu/hr)							
Level B/PR	43 (0.10)	11 (12)	2,769	891	682	1,573	2,036
Level C/PR-ESP	22 (0.05)	5.5 (6.0)	3,559	891	696	1,587	2,182
22.0 MW (75 MMBtu/hr)							
Level B/PR	43 (0.10)	16 (18)	3,440	1,337	797	2,134	2,712
Level C/PR-ESP	22 (0.05)	8.2 (9.0)	4,485	1,337	806	2,143	2,898
29.3 MW (100 MMBtu/hr)							
Level B/PR	43 (0.10)	22 (24)	4,046	1,783	910	2,693	3,375
Level C/PR-ESP	22 (0.05)	11 (12)	5,198	1,783	915	2,698	3,575

a All costs are in June 1985 dollars.

b PR = 90% SO2 removal (based on flue gas desulfurization)
ESP = Electrostatic precipitator

c The compliance option costs at the Baseline (PR) are the costs associated with daily fuel sampling/analysis at the FGD inlet and continuous SO2 emission monitoring at the FGD outlet.

d The PM control alternative (PR-ESP) include inlet fuel sampling/analysis, an outlet SO2 CEM, and surrogate costs for control device performance monitoring (instead of opacity CEM).

Table 14. Cost Effectiveness Results for Particulate Matter Control Alternatives for Oil-fired Boilers Subject to a Percent Reduction Requirement in Region V at 0.26 Capacity Factor (a)

Boiler Size PM Control Technique (b,c,d)	Actual PM Emission Rate, ng/J(lb/MMBtu)	Annual Emissions, Mg/y(ton/yr)	Annualized Cost, ($1000/yr)	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Level B/PR	43 (0.10)	1.0 (1.1)	648	- -
Level C/PR-ESP	22 (0.05)	0.5 (0.6)	696	93,900 (85,200)
7.3 MW (25 MMBtu/hr)				
Level B/PR	43 (0.10)	2.6 (2.8)	942	- -
Level C/PR-ESP	22 (0.05)	1.3 (1.4)	1,032	69,700 (63,200)
14.6 MW (50 MMBtu/hr)				
Level B/PR	43 (0.10)	5.2 (5.7)	1,406	- -
Level C/PR-ESP	22 (0.05)	2.6 (2.8)	1,553	56,900 (51,600)
22.0 MW (75 MMBtu/hr)				
Level B/PR	43 (0.10)	7.7 (8.5)	1,805	- -
Level C/PR-ESP	22 (0.05)	3.9 (4.3)	1,994	48,800 (44,300)
29.3 MW (100 MMBtu/hr)				
Level B/PR	43 (0.10)	10 (11)	2,186	- -
Level C/PR-ESP	22 (0.05)	5.2 (5.7)	2,395	40,500 (36,700)

a All costs are in June 1985 dollars.

b PR = 90% SO2 removal (based on flue gas desulfurization)
ESP = Electrostatic precipitator

c The compliance option costs at the Baseline (PR) are the costs associated with daily fuel sampling/analy at the FGD inlet and continuous SO2 emission monitoring at the FGD outlet.

d The PM control alternative (PR-ESP) include inlet fuel sampling/analysis, an outlet SO2 CEM, and surrogate costs for control device performance monitoring (instead of opacity CEM).

Table 15. Cost Effectiveness Results for Particulate Matter Control Alternatives for Oil-fired Boilers Subject to a Percent Reduction Requirement in Region V at 0.55 Capacity Factor (a,b)

Boiler Size PM Control Technique (b,c,d)	Actual PM Emission Rate, ng/J(lb/MMBtu)	Annual Emissions, Mg/y(ton/yr)	Annualized Cost, ($1000/yr)	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Level B/PR	43 (0.10)	2.2 (2.4)	824	- -
Level C/PR-ESP	22 (0.05)	1.1 (1.2)	876	47,600 (43,200)
7.3 MW (25 MMBtu/hr)				
Level B/PR	43 (0.10)	5.5 (6.0)	1,295	- -
Level C/PR-ESP	22 (0.05)	2.7 (3.0)	1,386	33,500 (30,400)
14.6 MW (50 MMBtu/hr)				
Level B/PR	43 (0.10)	11 (12)	2,036	- -
Level C/PR-ESP	22 (0.05)	5.5 (6.0)	2,182	26,800 (24,300)
22.0 MW (75 MMBtu/hr)				
Level B/PR	43 (0.10)	16 (18)	2,712	- -
Level C/PR-ESP	22 (0.05)	8.2 (9.0)	2,898	22,700 (20,600)
29.3 MW (100 MMBtu/hr)				
Level B/PR	43 (0.10)	22 (24)	3,375	- -
Level C/PR-ESP	22 (0.05)	11 (12)	3,575	18,300 (16,600)

a All costs are in June 1985 dollars.

b PR = 90% SO2 removal (based on flue gas desulfurization)
ESP = Electrostatic precipitator

c The compliance option costs at the Baseline (PR) are the costs associated with daily fuel sampling/analy at the FGD inlet and continuous SO2 emission monitoring at the FGD outlet.

d The PM control alternative (PR-ESP) include inlet fuel sampling/analysis, an outlet SO2 CEM, and surrogate costs for control device performance monitoring (instead of opacity CEM).

Table 16. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-Fired Boilers in Region V (0.26 Capacity Factor) (a)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
2.9 MW (10 MMBtu/hr)							
Baseline/SMC - 0.45	194 (0.45)	4.7 (5.1)	1,580	66	311	377	638
Level A/DMC - 0.30	129 (0.30)	3.1 (3.4)	1,650	66	336	402	673
Level B/FF - 0.20	22 (0.05)	0.5 (0.6)	1,784	66	335	401	695
Level B/SSS - 0.20	86 (0.20)	2.1 (2.3)	1,675	66	369	435	710
Level B/MC-ESP - 0.20	86 (0.20)	2.1 (2.3)	1,752	66	348	414	702
Level C/FF - 0.10	22 (0.05)	0.5 (0.6)	1,784	66	335	401	695
Level C/MC-VS - 0.10	43 (0.10)	1.0 (1.1)	2,146	57	382	439	798
Level C/MC-ESP - 0.10	43 (0.10)	1.0 (1.1)	1,789	66	348	414	708
Level D/FF - 0.05	22 (0.05)	0.5 (0.6)	1,784	66	335	401	695
Level D/MC-ESP - 0.05	22 (0.05)	0.5 (0.6)	1,821	66	349	415	714
7.3 MW (25 MMBtu/hr)							
Baseline/SMC - 0.45	194 (0.45)	11.6 (12.8)	2,823	164	418	582	1,050
Level A/DMC - 0.30	129 (0.30)	7.8 (8.5)	2,911	164	443	607	1,088
Level B/FF - 0.20	22 (0.05)	1.3 (1.4)	3,169	164	448	612	1,136
Level B/SSS - 0.20	86 (0.20)	5.2 (5.7)	2,953	164	478	642	1,130
Level B/MC-ESP - 0.20	86 (0.20)	5.2 (5.7)	3,115	164	458	622	1,137
Level C/FF - 0.10	22 (0.05)	1.3 (1.4)	3,169	164	448	612	1,136
Level C/MC-VS - 0.10	43 (0.10)	2.6 (2.8)	3,489	143	506	649	1,236
Level C/MC-ESP - 0.10	43 (0.10)	2.6 (2.8)	3,174	164	458	622	1,148
Level D/FF - 0.05	22 (0.05)	1.3 (1.4)	3,169	164	448	612	1,136
Level D/MC-ESP - 0.05	22 (0.05)	1.3 (1.4)	3,226	164	459	623	1,157

(Continued)

Table 16. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-Fired Boilers in Region V (0.26 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
14.6 MW (50 MMBtu/hr)							
Baseline/SMC - 0.60	258 (0.60)	31.0 (34.2)	4,994	328	619	947	1,776
Level A/DMC - 0.30	129 (0.30)	15.5 (17.1)	5,111	328	645	973	1,820
Level B/FF - 0.20	22 (0.05)	2.6 (2.8)	5,562	328	657	985	1,908
Level B/SSS - 0.20	86 (0.20)	10.3 (11.4)	5,177	328	683	1,011	1,869
Level B/MC-ESP - 0.20	86 (0.20)	10.3 (11.4)	5,472	328	664	992	1,900
Level C/FF - 0.10	22 (0.05)	2.6 (2.8)	5,562	328	657	985	1,908
Level C/MC-VS - 0.10	43 (0.10)	5.2 (5.7)	6,062	286	740	1,026	2,054
Level C/MC-ESP - 0.10	43 (0.10)	5.2 (5.7)	5,549	328	665	993	1,914
Level D/FF - 0.05	22 (0.05)	2.6 (2.8)	5,562	328	657	985	1,908
Level D/MC-ESP - 0.05	22 (0.05)	2.6 (2.8)	5,625	328	666	994	1,927
22.0 MW (75 MMBtu/hr)							
Baseline/SMC - 0.60	258 (0.60)	46.5 (51.2)	7,165	492	689	1,181	2,374
Level A/DMC - 0.30	129 (0.30)	23.3 (25.6)	7,309	492	717	1,209	2,424
Level B/FF - 0.20	22 (0.05)	3.9 (4.3)	7,885	492	737	1,229	2,541
Level B/SSS - 0.20	86 (0.20)	15.5 (17.1)	7,396	492	757	1,249	2,478
Level B/MC-ESP - 0.20	86 (0.20)	15.5 (17.1)	7,774	492	739	1,231	2,525
Level C/FF - 0.10	22 (0.05)	3.9 (4.3)	7,885	492	737	1,229	2,541
Level C/MC-VS - 0.10	43 (0.10)	7.8 (8.5)	8,436	429	839	1,268	2,704
Level C/MC-ESP - 0.10	43 (0.10)	7.8 (8.5)	7,869	492	740	1,232	2,542
Level D/FF - 0.05	22 (0.05)	3.9 (4.3)	7,885	492	737	1,229	2,541
Level D/MC-ESP - 0.05	22 (0.05)	3.9 (4.3)	7,963	492	741	1,233	2,576

(Continued)

Table 16. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-Fired Boilers in Region V (0.26 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
29.3 MW (100 MMBtu/hr)							
Baseline/SMC - 0.60	258 (0.60)	62.0 (68.3)	9,189	656	768	1,424	2,955
Level A/DMC - 0.30	129 (0.30)	31.0 (34.2)	9,360	656	796	1,452	3,010
Level B/FF - 0.20	22 (0.05)	5.2 (5.7)	10,025	656	826	1,482	3,150
Level B/SSS - 0.20	86 (0.20)	20.7 (22.8)	9,465	656	841	1,497	3,072
Level B/MC-ESP - 0.20	86 (0.20)	20.7 (22.8)	10,422	656	826	1,482	3,220
Level C/FF - 0.10	22 (0.05)	5.2 (5.7)	10,025	656	826	1,482	3,150
Level C/MC-VS - 0.10	43 (0.10)	10.3 (11.4)	10,655	572	946	1,518	3,334
Level C/MC-ESP - 0.10	43 (0.10)	10.3 (11.4)	10,530	656	827	1,483	3,239
Level D/FF - 0.05	22 (0.05)	5.2 (5.7)	10,025	656	826	1,482	3,150
Level D/MC-ESP - 0.05	22 (0.05)	5.2 (5.7)	10,635	656	828	1,484	3,258

a All costs in June 1985 dollars and include daily fuel sampling/analysis compliance costs.

b UNC = Uncontrolled
SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-VS = Single mechanical collector followed by venturi scrubber
FF = Fabric filter

c The PM control alternatives (i.e., Level A, Level B, Level C, and Level D) include the compliance costs for an opacity continuous emission monitor.

Table 17. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled-Fired Boilers in Region V (0.55 Capacity Factor)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Baseline/SMC - 0.45	194 (0.45)	9.8 (10.8)	1,599	139	382	521	784
Level A/DMC - 0.30	129 (0.30)	6.6 (7.2)	1,670	139	406	545	818
Level B/FF - 0.20	22 (0.05)	1.1 (1.2)	1,805	139	410	549	844
Level B/SSS - 0.20	86 (0.20)	4.4 (4.8)	1,696	139	447	586	863
Level B/MC-ESP - 0.20	86 (0.20)	4.4 (4.8)	1,773	139	426	565	855
Level C/FF - 0.10	22 (0.05)	1.1 (1.2)	1,805	139	410	549	844
Level C/MC-VS - 0.10	43 (0.10)	2.2 (2.4)	2,168	121	466	587	952
Level C/MC-ESP - 0.10	43 (0.10)	2.2 (2.4)	1,809	139	427	566	862
Level D/FF - 0.05	22 (0.05)	1.1 (1.2)	1,805	139	410	549	844
Level D/MC-ESP - 0.05	22 (0.05)	1.1 (1.2)	1,842	139	427	566	868
7.3 MW (25 MMBtu/hr)							
Baseline/SMC - 0.45	194 (0.45)	24.6 (27.1)	2,858	347	518	865	1,337
Level A/DMC - 0.30	129 (0.30)	16.4 (18.1)	2,946	347	544	891	1,375
Level B/FF - 0.20	22 (0.05)	2.7 (3.0)	3,206	347	554	901	1,429
Level B/SSS - 0.20	86 (0.20)	10.9 (12.0)	2,991	347	586	933	1,425
Level B/MC-ESP - 0.20	86 (0.20)	10.9 (12.0)	3,152	347	566	913	1,432
Level C/FF - 0.10	22 (0.05)	2.7 (3.0)	3,206	347	554	901	1,430
Level C/MC-VS - 0.10	43 (0.10)	5.5 (6.0)	3,526	302	638	940	1,541
Level C/MC-ESP - 0.10	43 (0.10)	5.5 (6.0)	3,211	347	567	914	1,443
Level D/FF - 0.05	22 (0.05)	2.7 (3.0)	3,206	347	554	901	1,430
Level D/MC-ESP - 0.05	22 (0.05)	2.7 (3.0)	3,263	347	567	914	1,452

(Continued)

Table 17. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-Fired Boilers in Region V (0.55 Capacity Factor) (Continued)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr)			Annualized Cost ($1,000/yr)
				Fuel	Nonfuel	Total	
14.6 MW (50 MMBtu/hr)							
Baseline/SMC - 0.60	258 (0.60)	65.6 (72.3)	5,051	694	755	1,449	2,285
Level A/DMC - 0.30	129 (0.30)	32.8 (36.1)	5,168	694	783	1,477	2,330
Level B/FF - 0.20	22 (0.05)	5.5 (6.0)	5,622	694	803	1,497	2,427
Level B/SSS - 0.20	86 (0.20)	21.9 (24.1)	5,236	694	830	1,524	2,389
Level B/MC-ESP - 0.20	86 (0.20)	21.9 (24.1)	5,531	694	810	1,504	2,419
Level C/FF - 0.10	22 (0.05)	5.5 (6.0)	5,622	694	803	1,497	2,427
Level C/MC-VS - 0.10	43 (0.10)	10.9 (12.0)	6,129	605	934	1,539	2,595
Level C/MC-ESP - 0.10	43 (0.10)	10.9 (12.0)	5,608	694	811	1,505	2,433
Level D/FF - 0.05	22 (0.05)	5.5 (6.0)	5,622	694	804	1,498	2,427
Level D/MC-ESP - 0.05	22 (0.05)	5.5 (6.0)	5,684	694	812	1,506	2,447
22.0 MW (75 MMBtu/hr)							
Baseline/SMC - 0.60	258 (0.60)	98.4 (108.4)	7,241	1,041	843	1,884	3,085
Level A/DMC - 0.30	129 (0.30)	49.2 (54.2)	7,386	1,041	873	1,914	3,136
Level B/FF - 0.20	22 (0.05)	8.2 (9.0)	7,964	1,041	904	1,945	3,264
Level B/SSS - 0.20	86 (0.20)	32.8 (36.1)	7,474	1,041	923	1,964	3,200
Level B/MC-ESP - 0.20	86. (0.20)	32.8 (36.1)	7,852	1,041	904	1,945	3,247
Level C/FF - 0.10	22 (0.05)	8.2 (9.0)	7,964	1,041	904	1,945	3,264
Level C/MC-VS - 0.10	43 (0.10)	16.4 (18.1)	8,527	907	1,078	1,985	3,461
Level C/MC-ESP - 0.10	43 (0.10)	16.4 (18.1)	7,948	1,041	905	1,946	3,265
Level D/FF - 0.05	22 (0.05)	8.2 (9.0)	7,964	1,041	904	1,945	3,264
Level D/MC-ESP - 0.05	22 (0.05)	8.2 (9.0)	8,041	1,041	907	1,948	3,282

(Continued)

Table 17. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled-Fired Boilers in Region V (0.55 Capacity Factor) (Continued)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
29.3 MW (100 MMBtu/hr)							
Baseline/SMC - 0.60	258 (0.60)	131.2 (144.5)	9,285	1,388	941	2,329	3,870
Level A/DMC - 0.30	129 (0.30)	65.6 (72.3)	9,456	1,388	972	2,360	3,928
Level B/FF - 0.20	22 (0.05)	10.9 (12.0)	10,124	1,388	1,014	2,402	4,080
Level B/SSS - 0.20	86 (0.20)	43.7 (48.2)	9,563	1,388	1,027	2,415	4,000
Level B/MC-ESP - 0.20	86 (0.20)	43.7 (48.2)	10,521	1,388	1,011	2,399	4,147
Level C/FF - 0.10	22 (0.05)	10.9 (12.0)	10,124	1,388	1,014	2,402	4,080
Level C/MC-VS - 0.10	43 (0.10)	21.9 (24.1)	10,770	1,209	1,230	2,439	4,310
Level C/MC-ESP - 0.10	43 (0.10)	21.9 (24.1)	10,628	1,388	1,013	2,401	4,168
Level D/FF - 0.05	22 (0.05)	10.9 (12.0)	10,124	1,388	1,015	2,403	4,080
Level D/MC-ESP - 0.05	22 (0.05)	10.9 (12.0)	10,733	1,388	1,015	2,403	4,187

a All costs in June 1985 dollars and include daily fuel sampling/analysis compliance costs.

b UNC = Uncontrolled
SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-VS = Single mechanical collector followed by venturi scrubber
FF = Fabric filter

c The PM control alternatives (i.e., Level A, Level B, Level C, and Level D) include the compliance costs for an opacity continuous emission monitor.

Table 18. Cost Effectiveness Results of Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-fired Model Boilers in Region V (0.26 Capacity Factor) (a)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c,d,e,f)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Baseline/SMC - 0.45	194 (0.45)	4.7 (5.1)	638	- -
Level A/DMC - 0.30	129 (0.30)	3.1 (3.4)	673	22,600 (20,500)
Level B/FF - 0.20	22 (0.05)	0.5 (0.6)	695	8,630 (7,830)
Level C/FF - 0.10	22 (0.05)	0.5 (0.6)	695	0 0
Level D/FF - 0.05	22 (0.05)	0.5 (0.6)	695	0 0
7.3 MW (25 MMBtu/hr)				
Baseline/SMC - 0.45	194 (0.45)	11.6 (12.8)	1,050	- -
Level A/DMC - 0.30	129 (0.30)	7.8 (8.5)	1,088	9,830 (8,920)
Level B/SSS - 0.20	86 (0.20)	5.2 (5.7)	1,130	16,300 (14,800)
Level C/FF - 0.10	22 (0.05)	1.3 (1.4)	1,136	1,550 (1,400)
Level D/FF - 0.05	22 (0.05)	1.3 (1.4)	1,136	0 0
14.6 MW (50 MMBtu/hr)				
Baseline/SMC - 0.60	258 (0.60)	31.0 (34.2)	1,776	- -
Level A/DMC - 0.30	129 (0.30)	15.5 (17.1)	1,820	2,820 (2,560)
Level B/SSS - 0.20	86 (0.20)	10.3 (11.4)	1,869	9,480 (8,610)
Level C/FF - 0.10	22 (0.05)	2.6 (2.8)	1,908	5,070 (4,600)
Level D/FF - 0.05	22 (0.05)	2.6 (2.8)	1,908	0 0

(Continued)

Table 18. Cost Effectiveness Results of Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-fired Model Boilers in Region V (0.26 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c,d,e,f)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
22.0 MW (75 MMBtu/hr)				
Baseline/SMC - 0.60	258 (0.60)	46.5 (51.2)	2,374	- -
Level A/DMC - 0.30	129 (0.30)	23.3 (25.6)	2,424	2,150 (1,960)
Level B/SSS - 0.20	86 (0.20)	15.5 (17.1)	2,478	6,950 (6,310)
Level C/FF - 0.10	22 (0.05)	3.9 (4.3)	2,541	5,380 (4,890)
Level D/FF - 0.05	22 (0.05)	3.9 (4.3)	2,541	0 0
29.3 MW (100 MMBtu/hr)				
Baseline/SMC - 0.60	258 (0.60)	62.0 (68.3)	2,955	- -
Level A/DMC - 0.30	129 (0.30)	31.0 (34.2)	3,010	1,790 (1,620)
Level B/SSS - 0.20	86 (0.20)	20.7 (22.8)	3,072	5,950 (5,400)
Level C/FF - 0.10	22 (0.05)	5.2 (5.7)	3,150	5,040 (4,580)
Level D/FF - 0.05	22 (0.05)	5.2 (5.7)	3,150	0 0

(Continued)

Table 18. Cost Effectiveness Results of Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-fired Model Boilers in Region V (0.26 Capacity Factor) (a) (Continued)

a All costs in June 1985 dollars and include daily fuel sampling/analysis compliance costs.

b UNC = Uncontrolled
SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-VS = Single mechanical collector followed by venturi scrubber
FF = Fabric filter

c The PM control alternatives (i.e., Level A, Level B, Level C, and Level D) include the compliance costs for an opacity continuous emission monitor.

d The least cost compliance option for the 0.20 lb PM/MM Btu control alternative was chosen from the SSS, FF, or MC-ESP control options.

e The least cost compliance option for the 0.10 lb PM/MM Btu control alternative was chosen from the MC-VS, FF, or MC-ESP control options.

f The least cost compliance option for the 0.05 lb PM/MM Btu control alternative was chosen from the FF or MC-ESP control options.

Table 19. Cost Effectiveness Results of Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-fired Model Boilers in Region V (0.55 Capacity Factor) (a)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c,d,e,f)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Baseline/SMC - 0.45	194 (0.45)	9.8 (10.8)	784	- -
Level A/DMC - 0.30	129 (0.30)	6.6 (7.2)	818	10,400 (9,440)
Level B/FF - 0.20	22 (0.05)	1.1 (1.2)	844	4,810 (4,370)
Level C/FF - 0.10	22 (0.05)	1.1 (1.2)	844	0 0
Level D/FF - 0.05	22 (0.05)	1.1 (1.2)	844	0 0
7.3 MW (25 MMBtu/hr)				
Baseline/SMC - 0.45	194 (0.45)	24.6 (27.1)	1,337	- -
Level A/DMC - 0.30	129 (0.30)	16.4 (18.1)	1,375	4,680 (4,250)
Level B/SSS - 0.20	22 (0.05)	10.9 (12.0)	1,425	9,130 (8,290)
Level C/FF - 0.10	22 (0.05)	2.7 (3.0)	1,430	610 (553)
Level D/FF - 0.05	22 (0.05)	2.7 (3.0)	1,430	0 0
14.6 MW (50 MMBtu/hr)				
Baseline/SMC - 0.60	258 (0.60)	65.6 (72.3)	2,285	- -
Level A/DMC - 0.30	129 (0.30)	32.8 (36.1)	2,330	1,360 (1,240)
Level B/SSS - 0.20	86 (0.20)	21.9 (24.1)	2,389	5,400 (4,900)
Level C/FF - 0.10	22 (0.05)	5.5 (6.0)	2,427	2,340 (2,120)
Level D/FF - 0.05	22 (0.05)	5.5 (6.0)	2,427	0 0

(Continued)

Table 19. Cost Effectiveness Results of Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-fired Model Boilers in Region V (0.55 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device - Nominal Emission Rate (b,c,d,e,f)	Actual PM Emission Rate ng/J (lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)		Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)	
22.0 MW (75 MMBtu/hr)						
Baseline/SMC - 0.60	258 (0.60)	98.4	(108.4)	3,085	-	-
Level A/DMC - 0.30	129 (0.30)	49.2	(54.2)	3,136	1,040	(943)
Level B/SSS - 0.20	86 (0.20)	32.8	(36.1)	3,200	3,900	(3,540)
Level C/FF - 0.10	22 (0.05)	8.2	(9.0)	3,264	2,590	(2,350)
Level D/FF - 0.05	22 (0.05)	8.2	(9.0)	3,264	0	0
29.3 MW (100 MMBtu/hr)						
Baseline/SMC - 0.60	258 (0.60)	131.2	(144.5)	3,870	-	-
Level A/DMC - 0.30	129 (0.30)	65.6	(72.3)	3,928	890	(810)
Level B/SSS - 0.20	86 (0.20)	43.7	(48.2)	4,000	3,270	(2,970)
Level C/FF - 0.10	22 (0.05)	10.9	(12.0)	4,080	2,450	(2,220)
Level D/FF - 0.05	22 (0.05)	10.9	(12.0)	4,080	0	0

a All costs in June 1985 dollars and include daily fuel sampling/analysis compliance costs.

b UNC = Uncontrolled
SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-VS = Single mechanical collector followed by venturi scrubber
FF = Fabric filter

c The PM control alternatives (i.e., Level A, Level B, Level C, and Level D) include the compliance costs for an opacity continuous emission monitor.

Table 19. Cost Effectiveness Results of Particulate Matter Control Alternatives for SO2 Low Sulfur Coal-controlled Coal-fired Model Boilers in Region V (0.55 Capacity Factor) (a) (Continued)

d The least cost compliance option for the 0.20 lb PM/MM Btu control alternative was chosen from the SSS, FF, or MC-ESP control options.

e The least cost compliance option for the 0.10 lb PM/MM Btu control alternative was chosen from the MC-VS, FF, or MC-ESP control options.

f The least cost compliance option for the 0.05 lb PM/MM Btu control alternative was chosen from the FF or MC-ESP control options.

Table 20. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Coal-fired Boilers Subject to a Percent Reduction Requirement in Region V at 0.26 Capacity Factor (a,b,c)

Boiler size, PM Control Device (d)	PM Emission Rate, ng/J (lb/MMBtu)	Annual PM Emissions, Mg/yr (tons/yr)	Capital Costs, $1,000	O & M Costs, $1,000/yr			Annualized Cost, $1,000/yr
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level C/PR	43 (0.10)	1.0 (1.1)	2,399	57	479	536	935
Level D/PR-FF	22 (0.05)	0.5 (0.6)	2,375	57	503	560	952
7.3 MW (25 MMBtu/hr)							
Level C/PR	43 (0.10)	2.6 (2.8)	3,833	143	605	748	1,391
Level D/PR-FF	22 (0.05)	1.3 (1.4)	3,998	143	636	779	1,446
14.6 MW (50 MMBtu/hr)							
Level C/PR	43 (0.10)	5.2 (5.7)	6,366	286	837	1,123	2,159
Level D/PR-FF	22 (0.05)	2.6 (2.8)	6,738	286	876	1,162	2,291
22.0 MW (75 MMBtu/hr)							
Level C/PR	43 (0.10)	7.7 (8.5)	8,761	429	936	1,365	2,793
Level D/PR-FF	22 (0.05)	3.9 (4.3)	9,363	429	982	1,411	2,987
29.3 MW (100 MMBtu/hr)							
Level C/PR	43 (0.10)	10.3 (11.4)	10,991	572	1,042	1,614	3,482
Level D/PR-FF	22 (0.05)	5.2 (5.7)	11,774	572	1,096	1,668	3,653

a All costs are in June 1985 dollars.

b Percent reduction control of SO2 emissions achieved with flue gas desulfurization.

c Compliance option costs at the PM baseline (PR) include inlet daily fuel sampling/analysis and an outlet SO2 emission monitor. The PM control alternative include inlet daily fuel sampling, an outlet SO2 emission monitor, and surrogate costs for control device performance monitoring (instead of opacity monitoring).

d PR = Percent reduction with a single mechanical collector followed by venturi scrubber
FF = Fabric filter

Table 21. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Coal-fired Boilers Subject to a Percent Reduction Requirement in Region V at 0.55 Capacity Factor (a,b,c)

Boiler Size, PM Control Device (d)	PM Emission Rate, ng/J (lb/MMBtu)	Annual PM Emissions, Mg/yr (tons/yr)	Capital Costs, $1,000	O & M Costs, $1,000/yr			Annualized cost, $1,000/yr
				Fuel	Nonfuel	Total	
2.9 MW (10 MMBtu/hr)							
Level C/PR	43 (0.10)	2.2 (2.4)	2,424	121	581	702	1,107
Level D/PR-FF	22 (0.05)	1.1 (1.2)	2,400	121	605	726	1,124
7.3 MW (25 MMBtu/hr)							
Level C/PR	43 (0.10)	5.5 (6.0)	3,877	302	751	1,053	1,712
Level D/PR-FF	22 (0.05)	2.7 (3.0)	4,041	302	784	1,086	1,763
14.6 MW (50 MMBtu/hr)							
Level C/PR	43 (0.10)	10.9 (12.0)	6,435	605	1,045	1,650	2,753
Level D/PR-FF	22 (0.05)	5.5 (6.0)	6,807	605	1,083	1,688	2,838
22.0 MW (75 MMBtu/hr)							
Level C/PR	43 (0.10)	16.4 (18.1)	8,853	907	1,185	2,092	3,618
Level D/PR-FF	22 (0.05)	8.2 (9.0)	9,455	907	1,230	2,137	3,742
29.3 MW (100 MMBtu/hr)							
Level C/PR	43 (0.10)	21.9 (24.1)	11,106	1,209	1,333	2,542	4,465
Level D/PR-FF	22 (0.05)	10.9 (12.0)	11,889	1,209	1,386	2,595	4,619

a All costs are in June 1985 dollars.

b Percent reduction control of SO2 emissions achieved with flue gas desulfurization.

c Compliance option costs at the PM baseline (PR) include inlet daily fuel sampling/analysis and an outlet SO2 emission monitor. The PM control alternative include inlet daily fuel sampling, an outlet SO2 emission monitor, and surrogate costs for control device performance monitoring (instead of opacity monitoring).

d PR = Percent reduction with a single mechanical collector followed by venturi scrubber
FF = Fabric filter

Table 22. Cost Effectiveness Results of Sulfur Dioxide Control Alternatives for Coal-fired Boilers in Region V at 0.26 Capacity Factor Subject to a Percent Reduction Requirement (a,b,c)

Boiler Size, PM Control Device (d,e)	PM Emission Rate, ng/J (lb/MMBtu)	Annual PM Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Level C/PR	43 (0.10)	1.0 (1.1)	935	- -
Level D/PR-FF	22 (0.05)	0.5 (0.6)	952	31,942 (28,978)
7.3 MW (25 MMBtu/hr)				
Level C/PR	43 (0.10)	2.6 (2.8)	1,391	- -
Level D/PR-FF	22 (0.05)	1.3 (1.4)	1,446	42,590 (38,640)
14.6 MW (50 MMBtu/hr)				
Level C/PR	43 (0.10)	5.2 (5.7)	2,159	- -
Level D/PR-FF	22 (0.05)	2.6 (2.8)	2,291	51,300 (46,500)
22.0 MW (75 MMBtu/hr)				
Level C/PR	43 (0.10)	7.7 (8.5)	2,793	- -
Level D/PR-FF	22 (0.05)	3.9 (4.3)	2,987	50,100 (45,400)
29.3 MW (100 MMBtu/hr)				
Level C/PR	43 (0.10)	10.3 (11.4)	3,482	- -
Level D/PR-FF	22 (0.05)	5.2 (5.7)	3,653	33,000 (30,000)

a All costs are in June 1985 dollars.

b Percent reduction control of SO2 emissions achieved with flue gas desulfurization.

c Compliance option costs at the PM baseline (PR) include inlet daily fuel sampling/analysis and an outlet SO2 emission monitor. The PM control alternative include inlet daily fuel sampling, an outlet SO2 emission monitor, and surrogate costs for control device performance monitoring (instead of opacity monitoring).

d PR = Percent reduction with a single mechanical collector followed by venturi scrubber
FF = Fabric filter

Table 23. Cost Effectiveness Results of Sulfur Dioxide Control Alternatives for Coal-fired Boilers in Region V at 0.55 Capacity Factor Subject to a Percent Reduction Requirement (a,b,c)

Boiler Size, PM Control Device (d,e)	PM Emission Rate, ng/J (lb/MMBtu)	Annual PM Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Level C/PR	43 (0.10)	2.2 (2.4)	1,107	- -
Level D/PR-FF	22 (0.05)	1.1 (1.2)	1,124	15,558 (14,114)
7.3 MW (25 MMBtu/hr)				
Level C/PR	43 (0.10)	5.5 (6.0)	1,712	- -
Level D/PR-FF	22 (0.05)	2.7 (3.0)	1,763	18,700 (16,900)
14.6 MW (50 MMBtu/hr)				
Level C/PR	43 (0.10)	10.9 (12.0)	2,753	- -
Level D/PR-FF	22 (0.05)	5.5 (6.0)	2,838	15,600 (14,200)
22.0 MW (75 MMBtu/hr)				
Level C/PR	43 (0.10)	16.4 (18.1)	3,618	- -
Level D/PR-FF	22 (0.05)	8.2 (9.0)	3,742	15,100 (13,700)
29.3 MW (100 MMBtu/hr)				
Level C/PR	43 (0.10)	21.9 (24.1)	4,465	- -
Level D/PR-FF	22 (0.05)	10.9 (12.0)	4,619	14,000 (12,700)

a All costs are in June 1985 dollars.

b Percent reduction control of SO2 emissions achieved with flue gas desulfurization.

c Compliance option costs at the PM baseline (PR) include inlet daily fuel sampling/analysis and an outlet SO2 emission monitor. The PM control alternative include inlet daily fuel sampling, an outlet SO2 emission monitor, and surrogate costs for control device performance monitoring (instead of opacity monitoring).

d PR = Percent reduction with a single mechanical collector followed by venturi scrubber
FF = Fabric filter

Table 24. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Wood-fired Boilers in Region V (0.26 Capacity Factor) (a)

Boiler Size, PM Control Device (b,c)	PM Emission Level/Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
2.9 MW (10 MMBtu/hr)							
Baseline/SMC	194 (0.45)	4.7 (5.1)	1,320	56	237	293	511
Level A/DMC	129 (0.30)	3.1 (3.4)	1,475	56	262	318	545
Level B/MC-LVS	86 (0.20)	2.1 (2.3)	1,806	56	272	328	625
Level B/MC-ESP	86 (0.20)	2.1 (2.3)	1,556	56	275	331	586
Level C/MC-MVS	43 (0.10)	1.0 (1.1)	1,812	56	273	329	627
Level C/MC-ESP	43 (0.10)	1.0 (1.1)	1,643	56	276	332	602
7.3 MW (25 MMBtu/hr)							
Baseline/SMC	194 (0.45)	11.6 (12.8)	2,643	139	357	496	935
Level A/DMC	129 (0.30)	7.8 (8.5)	2,735	139	382	521	973
Level B/MC-LVS	86 (0.20)	5.2 (5.7)	3,264	139	399	538	1,079
Level B/MC-ESP	86 (0.20)	5.2 (5.7)	3,040	139	398	537	1,041
Level C/MC-MVS	43 (0.10)	2.6 (2.8)	3,271	139	402	541	1,084
Level C/MC-ESP	43 (0.10)	2.6 (2.8)	3,179	139	399	538	1,066
14.6 MW (50 MMBtu/hr)							
Baseline/SMC	258 (0.60)	31.0 (34.2)	4,486	278	502	780	1,524
Level A/DMC	129 (0.30)	15.5 (17.1)	4,609	278	527	805	1,569
Level B/MC-LVS	86 (0.20)	10.3 (11.4)	5,289	278	556	834	1,712
Level B/MC-ESP	86 (0.20)	10.3 (11.4)	5,168	278	549	827	1,685
Level C/MC-MVS	43 (0.10)	5.2 (5.7)	5,299	278	562	840	1,720
Level C/MC-ESP	43 (0.10)	5.2 (5.7)	5,346	278	551	829	1,718

(Continued)

Table 24. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Wood-fired Boilers in Region V (0.26 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device (b,c)	PM Emission Level/Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
22.0 MW (75 MMBtu/hr)							
Baseline/SMC	258 (0.60)	46.5 (51.2)	6,119	417	632	1,049	2,067
Level A/DMC	129 (0.30)	23.3 (25.6)	6,273	417	659	1,076	2,117
Level B/MC-LVS	86 (0.20)	15.5 (17.1)	7,086	417	699	1,116	2,295
Level B/MC-ESP	86 (0.20)	15.5 (17.1)	6,982	417	685	1,102	2,264
Level C/MC-MVS	43 (0.10)	7.8 (8.5)	7,098	417	708	1,125	2,306
Level C/MC-ESP	43 (0.10)	7.8 (8.5)	7,203	417	688	1,105	2,304
29.3 MW (100 MMBtu/hr)							
Baseline/SMC	258 (0.60)	62.0 (68.3)	7,625	556	723	1,279	2,548
Level A/DMC	129 (0.30)	31.0 (34.2)	7,809	556	750	1,306	2,604
Level B/MC-LVS	86 (0.20)	20.7 (22.8)	8,748	556	802	1,358	2,815
Level B/MC-ESP	86 (0.20)	20.7 (22.8)	9,132	556	785	1,341	2,863
Level C/MC-MVS	43 (0.10)	10.3 (11.4)	8,761	556	814	1,370	2,829
Level C/MC-ESP	43 (0.10)	10.3 (11.4)	9,379	556	788	1,344	2,908

a All costs in June 1985 dollars.

b SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-LVS = Single mechanical collector followed by low pressure drop venturi scrubber
MC-MVS = Single mechanical collector followed by medium pressure drop venturi scrubber

c The PM control alternatives (i.e., Level A, Level B, and Level C) include the compliance costs for an opacity continuous emission monitor.

Table 25. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Wood-fired Boilers in Region V (0.55 Capacity Factor) (a)

Boiler Size, PM Control Device (b,c)	PM Emission Level/Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
2.9 MW (10 MMBtu/hr)							
Baseline/SMC	194 (0.45)	9.8 (10.8)	1,335	118	288	406	624
Level A/DMC	129 (0.30)	6.6 (7.2)	1,407	118	312	430	659
Level B/MC-LVS	86 (0.20)	4.4 (4.8)	1,823	118	327	445	744
Level B/MC-ESP	86 (0.20)	4.4 (4.8)	1,573	118	332	450	707
Level C/MC-MWS	43 (0.10)	2.2 (2.4)	1,828	118	330	448	747
Level C/MC-ESP	43 (0.10)	2.2 (2.4)	1,659	118	333	451	722
7.3 MW (25 MMBtu/hr)							
Baseline/SMC	194 (0.45)	24.6 (27.1)	2,672	294	437	731	1,173
Level A/DMC	129 (0.30)	16.4 (18.1)	2,764	294	463	757	1,212
Level B/MC-LVS	86 (0.20)	10.9 (12.0)	3,295	294	487	781	1,326
Level B/MC-ESP	86 (0.20)	10.9 (12.0)	3,071	294	486	780	1,287
Level C/MC-MWS	43 (0.10)	5.5 (6.0)	3,303	294	494	788	1,334
Level C/MC-ESP	43 (0.10)	5.5 (6.0)	3,210	294	488	782	1,313
14.6 MW (50 MMBtu/hr)							
Baseline/SMC	258 (0.60)	65.6 (72.3)	4,535	588	619	1,207	1,957
Level A/DMC	129 (0.30)	32.8 (36.1)	4,659	588	646	1,234	2,003
Level B/MC-LVS	86 (0.20)	21.9 (24.1)	5,342	588	687	1,275	2,160
Level B/MC-ESP	86 (0.20)	21.9 (24.1)	5,220	588	677	1,265	2,129
Level C/MC-MWS	43 (0.10)	10.9 (12.0)	5,353	588	700	1,288	2,174
Level C/MC-ESP	43 (0.10)	10.9 (12.0)	5,398	588	679	1,267	2,161

(Continued)

Table 25. Model Boiler Cost Analysis for Particulate Matter Control Alternatives for Wood-fired Boilers in Region V (0.55 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device (b,c)	PM Emission Level/Rate ng/J (lb/MMBtu)	Annual PM Emissions Mg/yr (tons/yr)	Capital Costs ($1,000)	O & M Costs ($1,000/yr) Fuel	Nonfuel	Total	Annualized Cost ($1,000/yr)
22.0 MW (75 MMBtu/hr)							
Baseline/SMC	258 (0.60)	98.4 (108.4)	6,188	882	784	1,666	2,690
Level A/DMC	129 (0.30)	49.2 (54.2)	6,343	882	813	1,695	2,743
Level B/MC-LVS	86 (0.20)	32.8 (36.1)	7,160	882	870	1,752	2,938
Level B/MC-ESP	86 (0.20)	32.8 (36.1)	7,054	882	849	1,731	2,900
Level C/MC-MVS	43 (0.10)	16.4 (18.1)	7,174	882	890	1,772	2,960
Level C/MC-ESP	43 (0.10)	16.4 (18.1)	7,275	882	853	1,735	2,941
29.3 MW (100 MMBtu/hr)							
Baseline/SMC	258 (0.60)	131.2 (144.5)	7,712	1,176	899	2,075	3,353
Level A/DMC	129 (0.30)	65.6 (72.3)	7,896	1,176	930	2,106	3,412
Level B/MC-LVS	86 (0.20)	43.7 (48.2)	8,840	1,176	1,003	2,179	3,645
Level B/MC-ESP	86 (0.20)	43.7 (48.2)	9,221	1,176	975	2,151	3,682
Level C/MC-MVS	43 (0.10)	21.9 (24.1)	8,857	1,176	1,029	2,205	3,674
Level C/MC-ESP	43 (0.10)	21.9 (24.1)	9,469	1,176	979	2,155	3,728

a All costs in June 1985 dollars.

b SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-LVS = Single mechanical collector followed by low pressure drop venturi scrubber
MC-MVS = Single mechanical collector followed by medium pressure drop venturi scrubber

c The PM control alternatives (i.e., Level A, Level B, and Level C) include the compliance costs for an opacity continuous emission monitor.

Table 26. Cost Effectiveness Results of Particulate Matter Control Alternatives for Wood-fired Model Boilers in Region V (0.26 Capacity Factor) (a)

Boiler Size, PM Control Device (b,c,d,e)	PM Emission Level ng/J(lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Baseline/SMC	194 (0.45)	4.7 (5.1)	511	- -
Level A/DMC	129 (0.30)	3.1 (3.4)	545	21,900 (19,900)
Level B/MC-ESP	86 (0.20)	2.1 (2.3)	586	39,700 (36,000)
Level C/MC-ESP	43 (0.10)	1.0 (1.1)	602	15,500 (14,000)
7.3 MW (25 MMBtu/hr)				
Baseline/SMC	194 (0.45)	11.6 (12.8)	935	- -
Level A/DMC	129 (0.30)	7.8 (8.5)	973	9,810 (8,900)
Level B/MC-ESP	86 (0.20)	5.2 (5.7)	1,041	26,300 (23,900)
Level C/MC-ESP	43 (0.10)	2.6 (2.8)	1,066	9,680 (8,780)
14.6 MW (50 MMBtu/hr)				
Baseline/SMC	258 (0.60)	31.0 (34.2)	1,524	- -
Level A/DMC	129 (0.30)	15.5 (17.1)	1,569	2,900 (2,630)
Level B/MC-ESP	86 (0.20)	10.3 (11.4)	1,685	22,500 (20,400)
Level C/MC-ESP	43 (0.10)	5.2 (5.7)	1,718	6,390 (5,800)

(Continued)

Table 26. Cost Effectiveness Results of Particulate Matter Control Alternatives for Wood-fired Model Boilers in Region V (0.26 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device (b,c,d,e)	PM Emission Level ng/J(lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
22.0 MW (75 MMBtu/hr)				
Baseline/SMC	258 (0.60)	46.5 (51.2)	2,067	- -
Level A/DMC	129 (0.30)	23.3 (25.6)	2,117	2,150 (1,950)
Level B/MC-ESP	86 (0.20)	15.5 (17.1)	2,264	19,000 (17,200)
Level C/MC-ESP	43 (0.10)	7.8 (8.5)	2,304	5,160 (4,680)
29.3 MW (100 MMBtu/hr)				
Baseline/SMC	258 (0.60)	62.0 (68.3)	2,548	- -
Level A/DMC	129 (0.30)	31.0 (34.2)	2,604	1,810 (1,640)
Level B/MC-LVS	86 (0.20)	20.7 (22.8)	2,815	20,400 (18,500)
Level C/MC-MVS	43 (0.10)	10.3 (11.4)	2,829	1,350 (1,230)

a All costs in June 1985 dollars.

b SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-LVS = Single mechanical collector followed by low pressure drop venturi scrubber
MC-MVS = Single mechanical collector followed by medium pressure drop venturi scrubber

c The PM control alternatives (i.e., Level A, Level B, and Level C) include the compliance costs for an opacity continuous emission monitor.

d The least cost compliance option for the 0.20 lb PM/MM Btu control alternative was chosen from the MC-LVS or MC-ESP control options.

e The least cost compliance option for the 0.10 lb PM/MM Btu control alternative was chosen from the MC-MVS or MC-ESP control options.

Table 27. Cost Effectiveness Results of Particulate Matter Control Alternatives for Wood-fired Model Boilers in Region V (0.55 Capacity Factor) (a)

Boiler Size, PM Control Device (b,c,d,e)	PM Emission Level ng/J(lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
2.9 MW (10 MMBtu/hr)				
Baseline/SMC	194 (0.45)	9.8 (10.8)	624	- -
Level A/DMC	129 (0.30)	6.6 (7.2)	659	10,670 (9,690)
Level B/MC-ESP	86 (0.20)	4.4 (4.8)	707	22,000 (19,900)
Level C/MC-ESP	43 (0.10)	2.2 (2.4)	722	6,860 (6,230)
7.3 MW (25 MMBtu/hr)				
Baseline/SMC	194 (0.45)	24.6 (27.1)	1,173	- -
Level A/DMC	129 (0.30)	16.4 (18.1)	1,212	4,760 (4,320)
Level B/MC-ESP	86 (0.20)	10.9 (12.0)	1,287	13,700 (12,500)
Level C/MC-ESP	43 (0.10)	5.5 (6.0)	1,313	4,760 (4,320)
14.6 MW (50 MMBtu/hr)				
Baseline/SMC	258 (0.60)	65.6 (72.3)	1,957	- -
Level A/DMC	129 (0.30)	32.8 (36.1)	2,003	1,400 (1,270)
Level B/MC-ESP	86 (0.20)	21.9 (24.1)	2,129	11,500 (10,500)
Level C/MC-ESP	43 (0.10)	10.9 (12.0)	2,161	2,930 (2,660)

(Continued)

Table 27. Cost Effectiveness Results of Particulate Matter Control Alternatives for Wood-fired Model Boilers in Region V (0.55 Capacity Factor) (a) (Continued)

Boiler Size, PM Control Device (b,c,d,e)	PM Emission Level ng/J(lb/MMBtu)	Annual Emissions, Mg/yr (ton/yr)	Annualized Cost, $1000/yr	Incremental Cost Effectiveness, $/Mg ($/ton)
22.0 MW (75 MMBtu/hr)				
Baseline/SMC	258 (0.60)	98.4 (108.4)	2,690	- -
Level A/DMC	129 (0.30)	49.2 (54.2)	2,743	1,080 (978)
Level B/MC-ESP	86 (0.20)	32.8 (36.1)	2,900	9,580 (8,690)
Level C/MC-ESP	43 (0.10)	16.4 (18.1)	2,941	2,500 (2,270)
29.3 MW (100 MMBtu/hr)				
Baseline/SMC	258 (0.60)	131.2 (144.5)	3,353	- -
Level A/DMC	129 (0.30)	65.6 (72.3)	3,412	900 (816)
Level B/MC-LVS	86 (0.20)	43.7 (48.2)	3,645	10,700 (9,670)
Level C/MC-MVS	43 (0.10)	21.9 (24.1)	3,674	1,330 (1,200)

a All costs in June 1985 dollars.

b SMC = Single mechanical collector
DMC = Dual mechanical collector
MC-ESP = Single mechanical collector followed by electrostatic precipitator
MC-LVS = Single mechanical collector followed by low pressure drop venturi scrubber
MC-MVS = Single mechanical collector followed by medium pressure drop venturi scrubber

c The PM control alternatives (i.e., Level A, Level B, and Level C) include the compliance costs for an opacity continuous emission monitor.

d The least cost compliance option for the 0.20 lb PM/MM Btu control alternative was chosen from the MC-LVS or MC-ESP control options.

e The least cost compliance option for the 0.10 lb PM/MM Btu control alternative was chosen from the MC-MVS or MC-ESP control options.